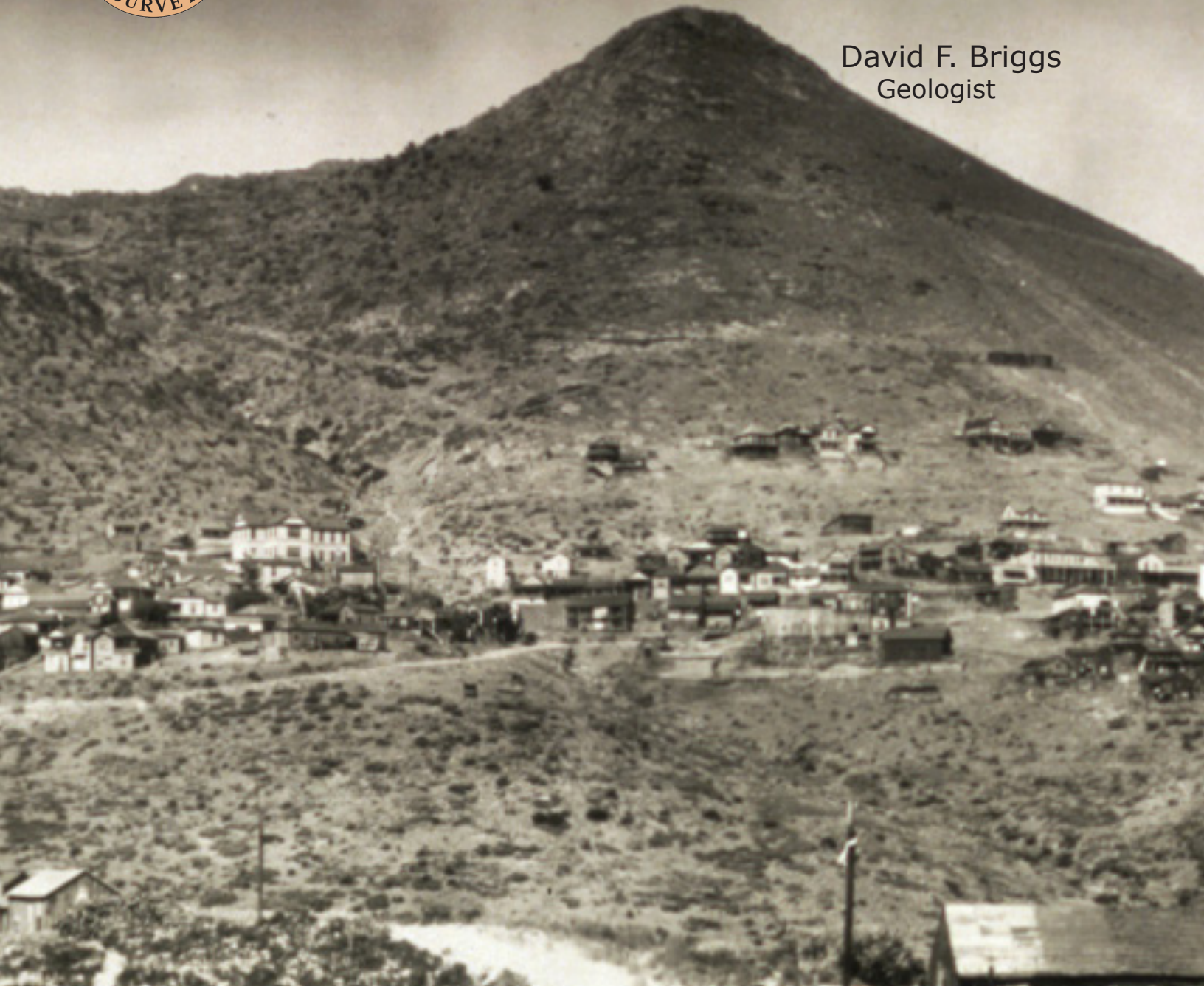


# History of the Verde Mining District, Jerome, Arizona

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Geologist



March 2018

**CONTRIBUTED REPORT** CR-18-D

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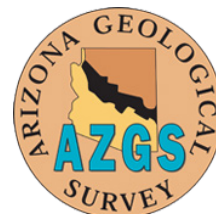
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## Table of Contents

Introduction -----	3
Geology of the Verde Mining District -----	6
Early Years (Prior to 1876) -----	17
United Verde - Rediscovery (1876 - 1888) -----	20
United Verde - William Andrews Clark (1888 - 1935) -----	23
United Verde Extension (1900 - 1938) -----	46
United Verde - Phelps Dodge Corporation (1935 - 1953) -----	57
Small Producers (1900 - 1950) -----	63
Haynes Massive Sulfide Deposit (1906 - 1935) -----	66
Jerome - Recent Years (1953 - Present) -----	67
Clarkdale - Recent Years (1953 - Present) -----	70
Reclamation Activities -----	71
Future of Verde Mining District -----	74
Acknowledgements -----	75
References -----	76

## Introduction

Situated along the northeastern slope of the Black Hills, the Verde Mining District is located approximately 25 miles northeast of Prescott, Arizona (Figure 1). The district's mines surround the community of Jerome, which is located at an elevation of about 5,200 feet. Precariously perched on the steep, northeastern slope of Cleopatra Hill, the Jerome mining camp overlooks the Verde River Valley, which was the site of district's smelting operations at Clarkdale and Clemenceau from 1915 until 1950.



Figure 1. Map of Arizona showing counties and the location of the Verde Mining District (triangle).

The copper mining operations of the Verde Mining District were similar to Arizona's other great copper districts in many ways, but differ in other respects. While they faced similar challenges related to the development of infrastructure required for profitable operation in remote localities, differences in the nature and character of the ores commonly necessitated innovative solutions to solve unique problems.

Arizona is known for its prolific copper production. Approximately 53% of the red metal historically produced in the United States (1845-2016) has been derived from Arizona's mines. More than one billion pounds of copper has been recovered from fourteen of Arizona's mining camps, including the Verde Mining District (Briggs, 2018).

The United Verde mine was Arizona's first recorded copper discovery by European explorers in A.D. 1583. While many early discoveries commonly occurred at sites where evidence of mineralization was exposed at the surface, the United Verde Extension (UVX) deposit was one of Arizona's first discoveries where an understanding of the district's geology played an important role in finding a concealed ore body.

Most of Arizona's copper occurrences are classified as porphyry copper  $\pm$  molybdenum deposits, which are related to the emplacement of molten magmas into the Earth's crust and its accompanying hydrothermal activity. With the exception of the porphyry copper system at Bisbee (180 million years before present), most of these deposits formed between 75 and 50 million years ago (Keith and Swan, 1995). Formed around hydrothermal vents on the seafloor approximately 1.74 billion years ago, volcanogenic massive sulfide deposits of the Verde Mining District are considerably older (Slack et. al., 2007).

Porphyry copper  $\pm$  molybdenum systems are characterized by large, relatively low-grade (less than 1% copper), disseminated bodies that range from several hundred million tons to several billion tons of ore. Early production from the larger porphyry mining districts was commonly derived from a number of mining operations that exploited high-grade ore bodies that occurred within a much larger zone of low-grade mineralization. Over time, advancements in technology and mining practices made it possible to economically recover copper from these intervening zones of low-grade mineralization.

Table 1. Summary of mine production data for the Verde Mining District (modified from DeWitt and Waegli, 1989 and Keith, 2017).

Mine	Period		Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
	From	To						
Alice	1966	1969	244	12,100	0	0	0	23
Anchor	1960	1961	140	11,700	0	0	6	178
Cleopatra	1910	1915	2,496	342,451	0	0	15	3,484
Cliff	1955	1959	332	29,400	0	0	0	184
Copper Chief	1901	1948	400,164	3,112,816	234,122	0	51,955	1,088,994
Dundee-Arizona	1918	1947	23,156	1,700,788	0	0	46	2,115
Florencia	1943	1949	26,890	1,679,547	0	0	715	4,731
Galveston	1941	1941	152	430	0	0	71	177
Green Monster	1942	1942	1,377	2,275	0	0	102	3,756
Jerome Verde	1901	1920	9,550	1,842,991	0	0	887	21,530
Silver Plate	1933	1935	59	878	0	0	189	698
United Verde	1883	1975	33,023,239	2,930,182,610	0	52,891,969	1,302,787	48,302,160
United Verde Extension	1915	1992	3,978,709	789,538,445	0	0	175,120	6,525,626
Verde Central	1929	1930	185,926	8,674,844	0	0	887	40,190
Other Mines (15)	1907	1965	2,663	275,095	0	0	224	2,655
Total	1883	1992	37,655,097	3,737,406,370	234,122	52,891,969	1,533,004	55,996,501

Unlike ores mined from Arizona's porphyry copper systems, volcanogenic massive sulfide deposits of the Verde Mining District were characterized by comparatively small, compact ore bodies that were very rich. More than 99% of the district's the copper production was derived from only two mining operations, the United Verde and the UVX mines (Table 1).

Approximately 33 million tons of ore, averaging 4.8% copper were mined at United Verde from 1883 to 1975, making it the largest volcanogenic massive sulfide producer in the United States (Briggs, 2018). It is reported to contain an additional unmined resource of 21 million tons, averaging 0.52% copper and 6.6% zinc (DeWitt and Waegli, 1989). As impressive as the United Verde is, the smaller UVX operation was one of the richest copper mines in North America with ore grades averaging 10.23% copper over its 23-year life (Lindberg, 1989).

Of an estimated 46.6 million tons of ore produced from volcanogenic massive sulfide systems in Arizona, approximately 80% of this tonnage was derived from the Verde Mining District (Lindberg, 1989). At 2017 metals prices (Cu - \$2.85/lb., Pb - \$1.13/lb., Zn - \$1.34/lb., Au - \$1,260/oz. and Ag - \$17.20/oz.), the value of metals recovered from the Verde Mining District totaled approximately \$13.6 billion (Anonymous, 2018).

During the late nineteenth century, initial discoveries of many mining districts throughout the west were made by lone prospectors, who journeyed into the remote regions with nothing more than a mule, a pick and a shovel. Few had the means to develop their holdings and commonly sold them to wealthy investors, who formed public companies, which had the financial resources that enabled these business ventures to realize their full potential. The United Verde Copper Company was unusual in that respect, in that during much of its life (1888-1935), more than 95% of its stock was owned by single individual, William A. Clark and his heirs.

Like all mining camps at the time, the growth and prosperity of the Jerome area depended on its accessibility to eastern markets. Mule- and oxen-drawn wagons that traversed rough mountainous roads to and from this remote mining camp were replaced by railroads in 1895, which significantly reduced the cost of producing and delivering the copper to market.

Like many copper producers, early operations in the Verde Mining District employed small water-jacketed blast furnaces to recover copper from high-grade oxide ores. Upon encountering unoxidized ores, treatment processes were modified to deal with its high sulfur content. This involved removing much of the sulfur by heap roasting prior to smelting. Unlike most of Arizona's copper producers where only a small percentage of ores have been treated by direct smelting methods, approximately 80% of the ores mined in the Verde Mining District were shipped directly to the smelter without prior beneficiation by gravity, flotation or other methods (Briggs, 2018).

Special mining practices were developed to safely extract the ores, which were particularly susceptible to mine fires resulting from spontaneous combustion due to the high sulfide content of the ore. Mine fires plagued the United Verde operation for more than three decades before being extinguished. Despite this handicap, mining operations at United Verde remained highly profitable, using a combination of underground and open pit methods.

Nearly three quarters of the historical ore production from the Verde Mining District was derived from underground operations. While mine drainage tunnels were commonly employed throughout the West to control groundwater flow in underground workings, their use in Arizona was restricted to a few localities, including the Verde Mining District.

## Geology of the Verde Mining District

The Verde Mining District is located in Arizona's Transition Zone, a broad physiographic province that separates the Colorado Plateau to the north from the Basin and Range Province to the south (Figure 2). The Transition Zone is characterized by rugged terrain, variably dissected alluvial basins, and large mountain ranges that are capped with erosional remnants of the Colorado Plateau (Menges and Pearthree, 1989).

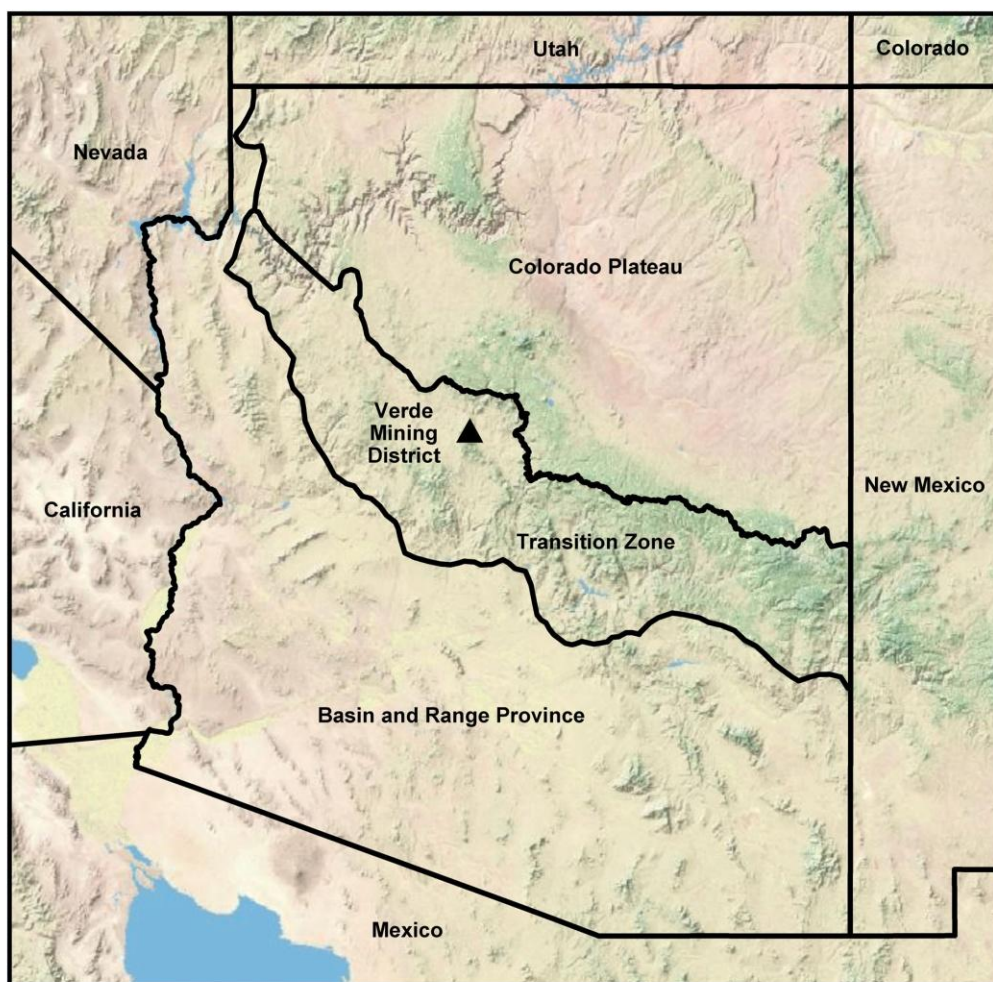


Figure 2. The Verde Mining District (triangle) and the major physiographic provinces of Arizona (modified from Menzes and Pearthree, 1989).

Outcropping on the northeastern flanks of Woodchute Mountain and Mingus Mountain, the early Proterozoic stratigraphic section that hosts the ores of the Verde Mining District occurs in a structurally uplifted fault block (i.e. horst) that is bounded by the north striking Warrior Fault on the west and the northwest trending Verde Fault on the northeast (Figure 3). Early Proterozoic units in the western, down-dropped, hanging wall of the Warrior Fault are unconformably overlain by a thin section of Paleozoic sediments, which is capped by late Miocene basaltic flows. Similarly, the early Proterozoic section is also concealed beneath Phanerozoic cover in the northeastern hanging walls of the Verde Fault and other normal faults that define the southeastern margin of the Verde Graben.

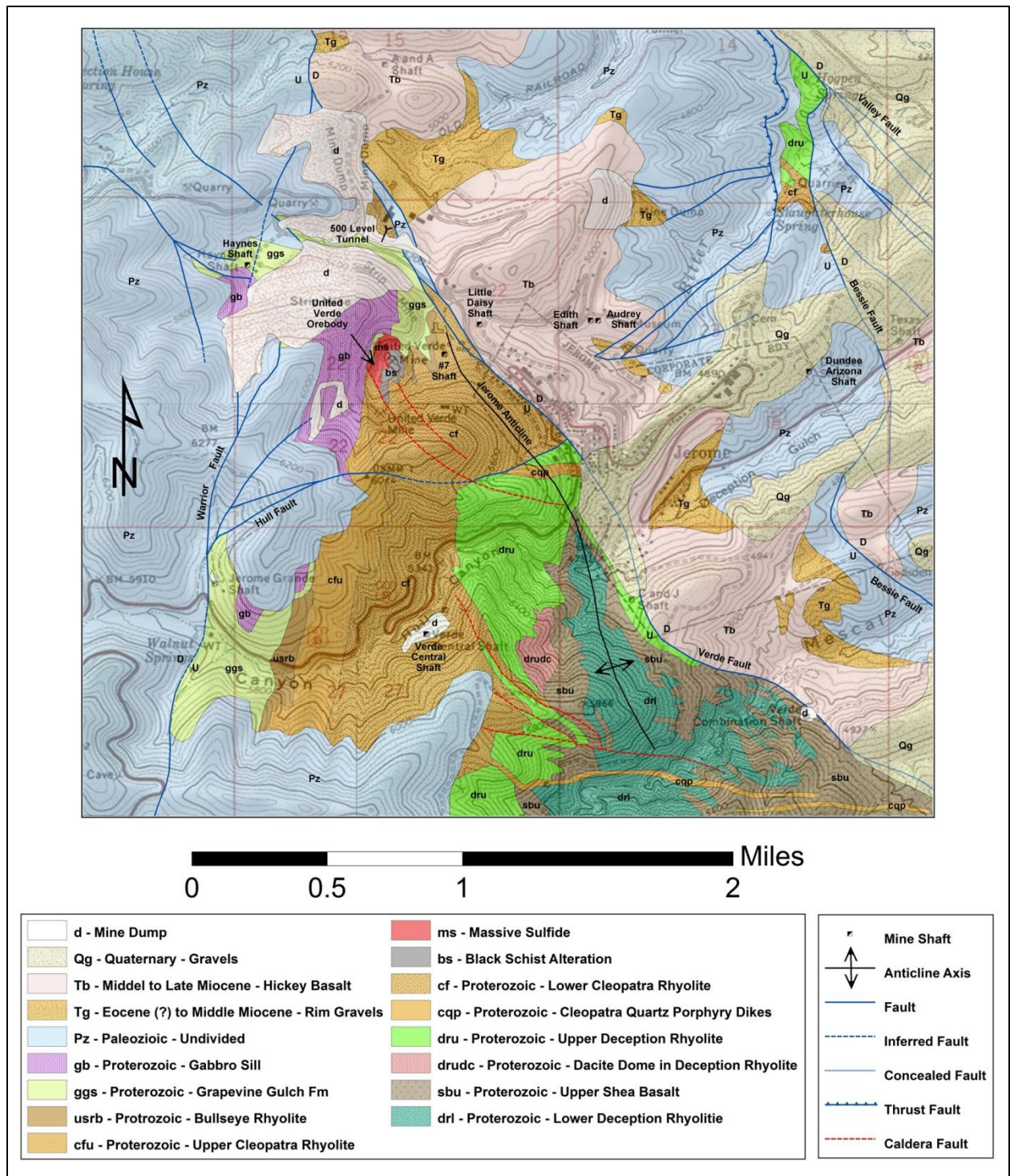


Figure 3. Geological map of the Verde Mining District (modified from Lindberg, 2008).

Early Proterozoic Stratigraphy and Structural Setting. The oldest stratigraphic units exposed in the Verde Mining District are a part of the early Proterozoic Ash Creek Group, which is characterized by at least two mafic to felsic cycles of largely submarine volcanics that are stratigraphically overlain by a thick sequence of volcanoclastic sediments deposited along the steep slopes of an ancient intraoceanic island

arc (Anderson, 1989 and Gustin, 1988). Evidence for subaqueous deposition of these units is supported by the presence of pillow basalts and hyaloclastitic (quench) textures, presence of black-smoker-type massive sulfide and exhalative chert, and turbidites and textures suggesting soft sediment deformation (Lindholm, 1991). The Ash Creek Group was deposited in a deep water oceanic environment, which is similar to the Izu-Bonin-Mariana arc, a modern day analog located in the western Pacific Ocean.

	Age	Formation	Symbol	Thickness (Ft)	Lithologic Description
Tertiary	Quat	Younger Gravels		20 - 50	Unconsolidated boulders, cobbles and pebbles
	Pleist				
	Plio	Verde Formation		1,400	Alluvial fan deposits (gravels with minor sand and silt) interbedded with lake sediments (marl, silt and fine-grained, fresh water limestone)
	Middle to Late Miocene	Hickey Basalt		1,200	Basalt with lesser amounts of agglomerate and basaltic sediments
Paleozoic	Eocene - Early Miocene	Rim Gravels		460	Gravel beds of boulders and cobbles, which are crudely bedded and cemented with lime; Dundee-Arizona deposit located at base of Rim Gravels
	Penn - Perm	Supai Formation		368	Limey red sandstone and siltstone with lesser amounts of light colored limestone and red shale
	Miss	Redwall Limestone		255 - 286	Massive cliff-forming limestone, coarsely crystalline cherty limestone and coarsely crystalline crinoidal limestone
	Devonian	Martin Formation		440 - 465	Impure dolomite and dolomitic limestone with thin shale and mudstone interbeds
		Chino Valley Formation		15 - 30	Dolomitic shale
	Cambrian	Tapeats Sandstone		0 - 100	Red, coarse sandstone and pebble conglomerate grading up into a yellow siltstone and marl
Precambrian	Early Proterozoic	Grapevine Gulch Formation		8,000 - 10,000 (?)	Thick section of fine to coarse-grained volcanoclastic sediments, which are interpreted to represent submarine turbidite deposits
		Bullseye Rhyolite		0 - 330	Dacite flow dome and breccia complex with thin horizons of volcanoclastics or vitro-clastic tuff at the base and top
		Upper Cleopatra Rhyolite		0 - 800	Unaltered volcanoclastics, rhyodacite flows and crystal tuffs; lead isotope age - 1,738.5 my
		Lower Cleopatra Rhyolite		2,000 - 3,000	Altered rhyolitic flows with shallow level intrusives, vitroclastic tuff and volcanoclastics; United Verde and UVX deposits located at top of Lower Cleopatra Rhyolite
		Upper Deception Rhyolite		1,100 (?)	Rhyolitic flows, crystal lithic tuff and fine- to coarse-grained volcanoclastics; Verde Cenral deposit located at top of Upper Deception Rhyolite
		Upper Shea Basalt		200 - 700 (?)	Amygdaloidal basaltic flows, locally pillowed with hyaloclastites; interfingers with Deception Rhyolite
		Lower Deception Rhyolite		1,000 (?)	Rhyolitic flows crystal lithic tuff and fine to coarse-grained volcanoclastics; interfingers with Shea Basalt
		Lower Shea Basalt		1,300 (?)	Amygdaloidal basaltic flows, locally pillowed with hyaloclastites
		Buzzard Rhyolite		3,500 (?)	Porphyritic rhyolitic lavas, fine- to coarse-grained sediments and volcanoclastics. Contorted flow banding and vesicles are common
		Gaddes Basalt		2,000 - 2,500 (?)	Pillow basalts with interbedded pyroclastic horizons, intercalated rhyolite flows occur near the top of the unit

Figure 4. Stratigraphic section of the Verde Mining District. Reported thicknesses for the early Proterozoic section are likely to be high, due to isoclinal folding (modified after Anderson and Creasey, 1958, Gustin, 1988, and Lindberg, 2008).

The early Proterozoic section has been folded about the north-northwest trending Jerome Anticline, which plunges to the north. The Gaddes Basalt and Buzzard Rhyolite of the lower volcanic cycle of the Ash Creek Group are exposed in the southeast portion of the Verde Mining District, while the Shea Basalt, Deception Rhyolite, Cleopatra Rhyolite and Bullseye Rhyolite of the upper volcanic cycle outcrop in the northwestern portion of the district. The overlying Grapevine Gulch Formation consists of a thick sequence of fine- to coarse-grained volcanoclastic sediments that were deposited along steep slopes of the volcanic centers by turbidity currents (Gustin 1988). A description of the rocks in the stratigraphic section are shown Figure 4.

Each of the bimodal volcanic cycles are characterized by isolated felsic volcanic centers that overlie and interfinger with oceanic basalts. A palinspastic restoration of the younger volcanic cycle shows the Copper Chief mine area, located approximately four miles southeast of Jerome, lies near the southern edge of a northward thickening section of rhyolitic lavas, pyroclastics and flow breccias. At its southern margin, the Deception Rhyolite is interleaved with the Shea Basalt (Figure 3). Moving northward silica-rich extrusives dominate with the eruption of the lower member of the Cleopatra Rhyolite resulting in the development of a caldera in the Jerome area (Lindberg, 2008).

The United Verde and UVX mines, the district's largest producers, are volcanogenic massive sulfide deposits, which were formed at the top of the lower member of the Cleopatra Rhyolite, while the smaller Verde Central deposit occurs at the top of the older Deception Rhyolite (Gustin 1988 and Lindberg 2008). Specimens of the lower member of the Cleopatra Rhyolite and Deception Rhyolite are shown in Figure 5.



Figure 5. Representative samples of the lower member of the Cleopatra Rhyolite (left) and underlying Deception Rhyolite (right), which are on display at the Jerome State Historic Park (photos provided by Jan Rasmussen).

Origin of Volcanogenic Massive Sulfide Ores. The volcanogenic massive sulfide ores at United Verde and UVX were deposited on the sea floor immediately following the deposition of the lower member of the Cleopatra Rhyolite, approximately 1,738.5 million years ago (Slack, et. al., 2007). Heat from the recently erupted volcanic pile created huge convection cells consisting mainly of seawater that circulated through and altered large volumes of the lower member of the Cleopatra Rhyolite prior to venting

through seafloor fractures as superheated hydrothermal fluids containing iron, sulfur, copper, zinc, silver and gold (Lindberg 2008).

As hydrothermal fluids emanated from these vents, sulfides were precipitated at the rock-water interface immediately above the vent sites, initially depositing pyrite, chalcopyrite and sphalerite. Ore-bearing fluids continued to pass through the earlier deposited sulfide layers as the sulfide mound grew larger, replacing much of the original sphalerite with chalcopyrite. Overtime, stratigraphically lower portions of the sulfide deposit became progressively enriched in copper as zinc and precious metals were leached and re-precipitated at higher levels. Proximal sulfide deposition above the vent area was accompanied by simultaneous chemical deposition of thin distal layers of chert exhalite. During final stages of mineralization, cooler fluids rich in silica and iron deposited jasperoidal horizons on top of massive sulfide bodies (Lindberg 2008).

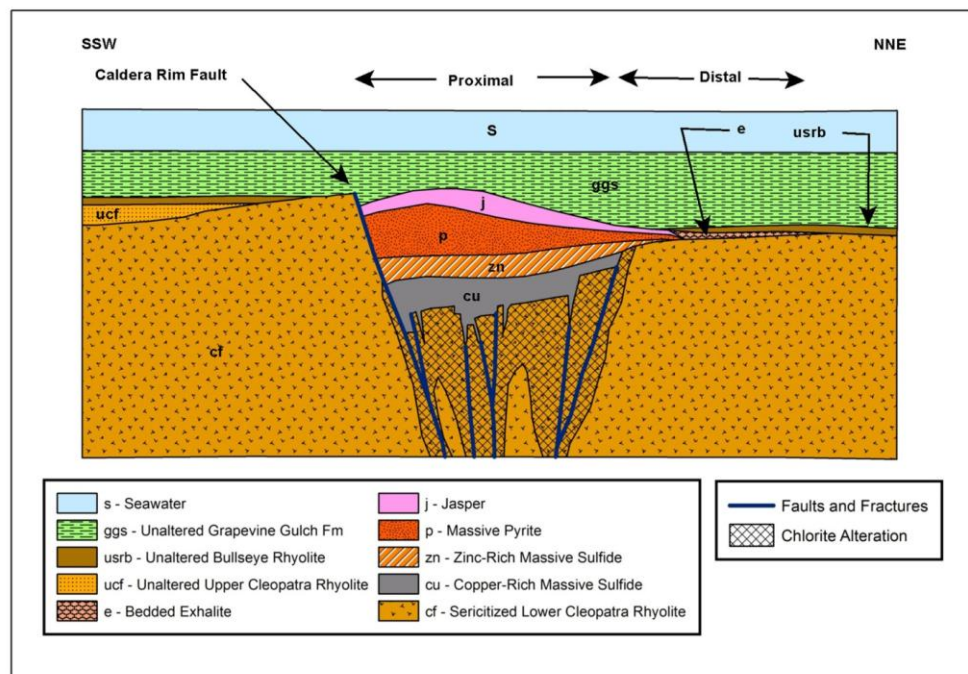


Figure 6. Simplified schematic cross section prior to the emplacement of the gabbro sill and folding, which shows the distribution of alteration and metals assemblages at the United Verde volcanogenic massive deposit. Hydrothermal convection cells of hot seawater altered much of the Lower Cleopatra Rhyolite to a sericitic assemblage. Magnesium-rich chlorite alteration occurs in fractured zones underlying the seafloor vents, where the metals were deposited at the rock-water interface. The post-mineral Upper Cleopatra Rhyolite, Bullseye Rhyolite and the Grapevine Gulch formation are unaltered (modified from Lindberg, 1986a).

This model of ore deposition explains the observed alteration and metal zoning patterns at the United Verde deposit (Figure 6). It also accounts for the presence of replacement textures that occur in the lower portions of the massive sulfide lens. These replacement textures were the primary reason why many geologists originally believed the United Verde ore body formed by the selective replacement of wall rocks adjacent to a quartz porphyry intrusive body, located in the footwall of the deposit (Anderson

and Creasey, 1958 and Lindberg, 2008). This quartz porphyry body is now interpreted to be a part of the stratigraphic succession of rhyolitic volcanics (Anderson and Nash, 1972).



Figure 7. "Black Smoker" sulfide chimney from 500-foot level of the United Verde open pit (left) and "White Smoker" from the UVX mine (middle) are very similar to modern day "black smoker" observed on the modern seafloor in near the Mariana Islands (right). Samples of black and white smokers are on display at the Jerome State Historic Park. [photos provided by Jan Rasmussen and the National Oceanic and Atmospheric Administration (NOAA)].

Description of Volcanogenic Massive Sulfide Deposits. Ores from both the United Verde and UVX deposits exhibit textures that are remarkably similar to modern day analogs known as "black and white smokers" that have been observed in oceanic basins at numerous localities around the world (Lindberg, 1992). Black smokers typically form above hotter hydrothermal vents associated with sulfide rich ores, while white smokers are located in cooler, peripheral areas above submarine hot springs that are commonly associated with silica-rich gold ores (Figure 7).

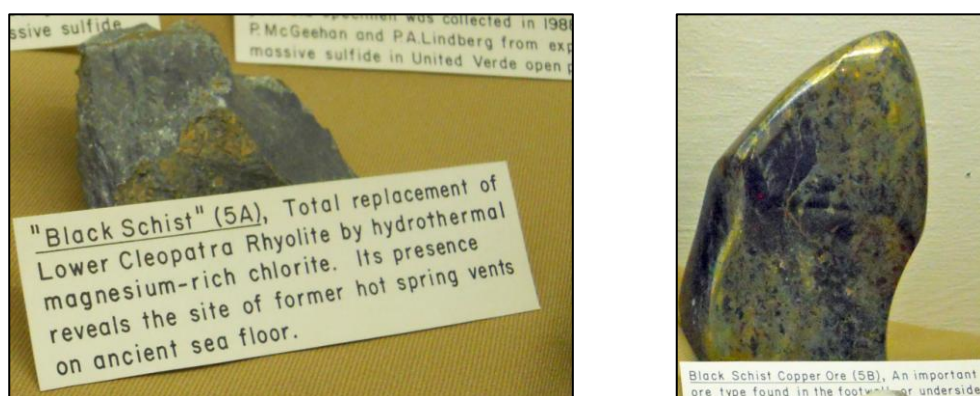


Figure 8. Representative samples of black schist (left) and black schist ore (right) from the United Verde Pit. Black schist marks the site of hot spring vents on the ancient sea floor. The brass-color mineral in the black schist ore is chalcopyrite. These samples are on display at the Jerome State Historic Park (photo provided by Jan Rasmussen).

Supergene-Enriched Copper Ore (6G), UVX-100, 1400 foot level. During the weathering process copper was leached out of the gossan coprock(6F) and concentrated in the groundwater. Copper values were greater than 10% in the drift. The drift is composed of (6G).

Copper Ore (6B), United Verde open pit. Chalcopyrite ( $\text{CuFeS}_2$ ) partially replacing banded massive sulfide.

Zinc Ore (6D), United Verde open pit. Banded sphalerite ( $\text{ZnS}$ ) with chalcopyrite.

Copper contents of the massive sulfide body generally diminish upward and peripherally outward into zinc-rich zones containing up to 15% sphalerite that are generally characterized by alternating bands of zinc- and pyrite-rich layers about 1/4-inch thick (Anderson and Creasey, 1958). Figure 9 illustrates copper- and zinc-rich ores within the massive sulfide lens at United Verde.



Page 12 of 83

The silica content of the massive sulfide lens at United Verde generally increases upward forming a silica-rich massive pyrite shown in Figure 10, which is capped with large bodies of jasperoid or flinty quartz that represent the final stages of the mineralizing event at the United Verde ore body (Lindberg, 2008).

Primary textures observed in the upper portions of the United Verde deposit locally exhibit fine alternating banding of chert and sulfide layers, which represent original bedding (Figure 11). Thin-bedded, chemical sediments, known as chert exhalites were deposited on the sea floor in areas distal from the hydrothermal vents. Soft-sediment deformation and slumping textures are commonly observed in the chert exhalites shown in Figure 11.



Figure 11. Finely layered zinc-copper ore (left) and chert exhalite (right) from the United Verde pit, which are on display at the Jerome State Historic Park (photos provided by Jan Rasmussen).

Post-Mineral Stratigraphy and Subsequent Regional Metamorphism. Unaltered volcanics and volcaniclastics of the upper member of the Cleopatra Rhyolite and tuffaceous, turbiditic sediments of the overlying Grapevine Gulch Formation located in the hanging wall of the United Verde deposit were deposited on top of the sulfide-rich lens and post-date the mineralization (Figure 5). These post-mineral units were subsequently cut by a synvolcanic gabbro, which is represented by a large sill-like intrusive body that occurs in the western hanging wall of the United Verde massive sulfide deposit (Lindberg, 1992).

Following deposition, units of the Ash Creek Group were deformed into a series of largely northwest trending folds and regionally metamorphosed under greenschist facies conditions (400 to 500°C. at depth of 5 to 50 km) (Anderson, 1989 and Anderson and Nash, 1972). The region was uplifted and underwent a considerable amount of erosion prior to the deposition of the relatively thin Paleozoic stratigraphic sequence (about 1,200 feet) above a pronounced angular unconformity developed at the top of the early Proterozoic section.

Phanerozoic Stratigraphy and Structural Deformation. Paleozoic strata are represented by a gently northeast dipping sequence of clastic and carbonate sediments, represented by the Cambrian Tapeats

Sandstone, Devonian Chino Valley and Martin Formations, Mississippian Redwall Limestone, and the Pennsylvanian-Permian Supai Formation (Figure 4). A second major unconformity developed at the top of the Paleozoic section following the regional uplift during the Laramide Orogeny, which occurred approximately 70 to 75 million years ago. This regional uplift was accompanied by numerous high angle reverse faults in Verde Valley area, including ancestral Verde, Bessie and Valley faults. A gravity slide block of gently tilted Paleozoic units above the Chino Valley Formation in the hanging wall of the ancestral Verde Fault was displaced approximately several hundred feet to the northeast along a flat-lying fault. This displacement and subsequent early Tertiary erosion created a deep channel that was later filled with Eocene (?) to early Miocene Rim Gravels (Figure 12). These gravels were subsequently covered by middle to late Miocene Hickey Basalt (10 to 15 million years ago) prior to the onset of extensional tectonism that created the Verde Valley between 8 and 10 million years ago (Lindberg, 2008).

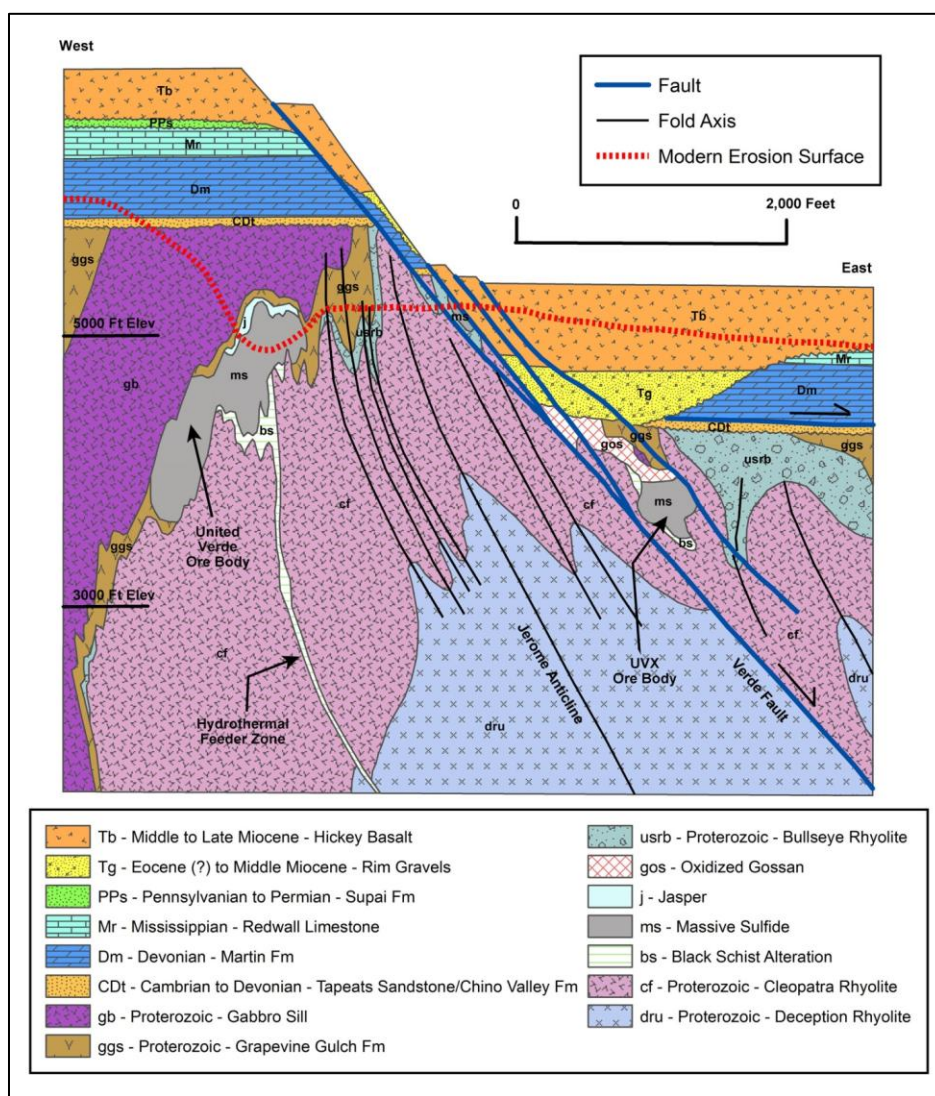


Figure 12. East-west geological cross section showing relationship between the United Verde and UVX ore bodies (modified from Lindberg, 1992).

Normal faulting along the reactivated the ancestral Verde, Bessie and Valley faults formed the Verde Valley, a northwest-southeast elongated half-graben. The Verde Valley is bounded on the north and east by the Mogollon Rim, a prominent escarpment that marks the southern edge of the Colorado Plateau. During the late Miocene the ancestral drainage of the Verde Valley was blocked by structural subsidence and volcanic activity along its southern margin resulting in the development of lacustrine, fluvial and volcanoclastic sediments on the valley floor, which was accompanied by concurrent deposition of thick alluvial fan deposits along the flanks of the surrounding highlands (House and Pearthree, 1993).

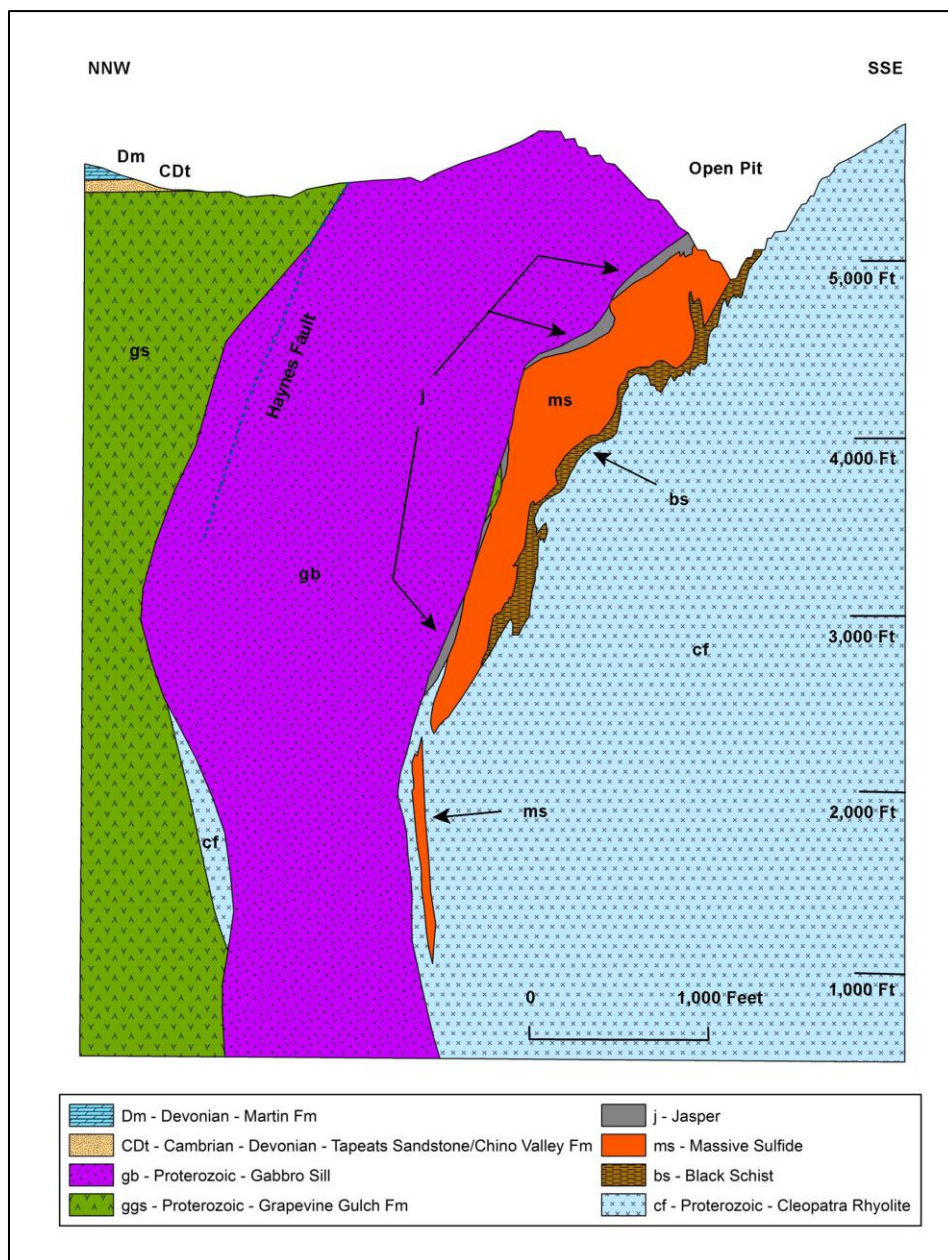


Figure 13. Diagrammatic geological cross-section showing metal zoning and alteration in the United Verde deposit (modified from Anderson and Creasey, 1958).

Structural Setting of United Verde Ore Body. Volcanogenic massive sulfide ores and host rocks at the United Verde mine were deformed in series of open folds that generally plunge north-northwest. The volcanogenic massive sulfide now occurs as a pipe-like body that extends from the surface to a depth of 4,500 feet; plunging 50 to 65 degrees to the north on a N20°W axis (Anderson and Nash, 1972). A NNW-SSE cross-section of the United Verde deposit is shown in Figure 13. The altered lower member of the Cleopatra Rhyolite occupies the footwall of the massive sulfide ore body, while the unaltered upper member of the Cleopatra Rhyolite, Grapevine Gulch Formation and post-mineral gabbroic sill are located in the hanging wall (Gustin, 1988).

Ore Chemistry and Mineralogy at the United Verde Mine. Ores at the United Verde operation were subdivided into four classes, which were handled separately by the mining operation. The four classes of ore include: oxide ore, iron ore, silica ore and converter ore (Smith and Sirdevan, 1922). Chemical analyses of ore classes treated by the Clarkdale smelter during 1918 are shown in Table 2.

Table 2. Chemical analyses of ore classes treated by the Clarkdale smelter during 1918 (Smith and Sirdevan, 1922).

Class of Ore	Cu %	Zn %	Au Oz./Ton	Ag Oz./Ton	Fe %	Insoluble %	SiO <sub>2</sub> %	Al <sub>2</sub> O <sub>3</sub> %	S %
Oxide	1.42	0.2	0.225	8.37	31.5	40.4	34.1	5.7	4.2
Iron	6.14	2.6	0.025	1.94	32.5	11.5	8.8	3.3	37.3
Silica	5.05	1.2	0.025	2.06	25.5	24.8	19.3	10.4	21.1
Converter	2.06	0.6	0.061	2.32	11.2	71.3	67.0	9.9	3.8

Primarily mined in the oxidized zone located above the 160-foot level, oxidized ores contained small amounts of remnant sulfide. They generally contained less copper and higher gold and silver values than other ore classes (Table 2). Iron ore was characterized by massive sulfide ores, containing less than 15% silica. Ores containing between 15 to 50% silica were classified as silica ores. Silica ores included all of the black schist ore, massive sulfide ores containing more than 15% silica, and ore-bearing, sericitized rhyolite containing less than 50% silica. Containing more than 50% silica, converter ores were essential for use as flux in the converters and for fettling (i.e. repairing) the reverberatory furnaces. It was derived from sericitized rhyolite in the footwall of the deposit as well as jasperoid bodies overlying the massive sulfide body that commonly contained elevated values in gold and silver (Mills, 1925).

Table 3. Typical mineralogical composition of ore classes at United Verde (Smith and Sirdevan, 1922).

Mineralogy	Oxide Ore %	Iron Ore %	Silica Ore %	Converter Ore %
Pyrite	3	59	28	5.75
Chalcopyrite	-	18	16	1.00
Sphalerite	-	4	2	0.50
Chalcocite	2	-	-	1.50
Cuprite, native copper and carbonates	-	-	-	0.25
Cuprite	1	-	-	-
Sulfates and carbonates (iron, copper and lime)	3	-	-	-

Mineralogy	Oxide Ore %	Iron Ore %	Silica Ore %	Converter Ore %
Iron oxides	46	2	2	11.00
Chlorite	-	-	38	6.00
Quartz	28	5	5	54.00
Silicates (sericite, hornblende, kaolin, etc)	15	10	9	20.00
Calcite and siderite	-	2	-	-
Total	100	100	100	100.00

Unoxidized mineralogy of the United Verde deposit is characterized by an assemblage composed of 40 to 80% sulfide minerals, chiefly consisting of pyrite with lesser amounts of interstitial quartz, dolomite and ankerite. Sulfides other than pyrite (primarily chalcopyrite and sphalerite) constitute less than 25% of the unoxidized ore. Minor constituents include bornite, arsenopyrite, galena, tennantite and electrum (Dewitt and Waegli, 1989).

Oxidation and Supergene Enrichment. The primary sulfide mineralogy at both the United Verde and UVX deposits was modified by weathering and supergene processes. Natural oxidation above the 160-foot level at the United Verde mine only occurred for a few million years as the apex of the massive sulfide body was exhumed by erosional processes. It was also oxidized by mine fires between the 160- to 600-foot levels of the underground mining operation (Lindberg 2008). The oxide-supergene mineral assemblage includes cuprite, chalcocite, azurite, malachite, native copper, wire silver, copper hydroxides, and hydrous copper sulfate minerals (Dewitt and Waegli, 1989).

In contrast, the UVX deposit was exposed to a much longer period of natural oxidation and supergene enrichment, which began with the development of the ancestral Verde Fault during the Laramide uplift. This was followed by a gravity slide that moved the Paleozoic section above the Chino Valley Formation approximately 300 to 400 feet to the northeast (Figure 12). Subsequent erosion of this area cut a 460-foot deep channel removing much of the Paleozoic and Proterozoic cover immediately overlying the UVX deposit. This paleo-channel is now filled with Eocene to early Miocene Rim Gravels. The UVX deposit was exposed for at least 70 million years of oxidation and supergene enrichment, resulting in the development of an extensive oxidized gossan above the deposit and its underlying enriched supergene ore body (Lindberg 2008). The enriched bonanza ores at UVX consisted almost entirely of chalcocite with cuprite and native copper being locally abundant in some of the stopes (Anderson and Creasey, 1958).

## Early Years (Prior to 1876)

Early nomadic inhabitants of central Arizona left their mark throughout the region in the form of scratched designs and pictographs that date from 9,000 B.C. (McCarthy, 2014). Native Americans of the Sinagua Culture arrived in the Verde Valley around A.D. 650. Over the next eight centuries, the region was home for 6,000 to 8,000 inhabitants, who cultivated the fertile lands and lived in cliff dwellings and pueblos erected at easily defended sites scattered throughout the area (Griffing, 2012). Archeological evidence suggests these large agricultural communities vanished by A.D. 1425. They were gradually

replaced by small, nomadic hunter-gatherer bands of Yavapai and Tonto Apache, who initially arrived in Verde Valley around A.D. 1300 and A.D. 1450, respectively.

No one knows when copper was originally discovered along the eastern slope of the Black Hills, which overlooks the Verde River Valley. Primitive mine workings, stone hammers and other artifacts found throughout the Verde Mining District suggest oxidized copper minerals were mined by Native Americans, who used them for personal adornment and as dyes for their blankets and pottery (O'Brien, 1991).

Spanish expeditions from Mexico arrived in present-day Arizona and New Mexico around A.D. 1539 in search of riches reported to be located in the fabled Seven Cities of Cibola. Although this legend was ultimately proved false, subsequent expeditions to this region were more successful. During A.D. 1582-83, Antonio de Espejo followed the Rio Grande River into north-central New Mexico before heading west into central Arizona. In his journal, he reported the discovery of rich silver ore in an area south of the San Francisco Peaks on May 8, 1583. The same locality was described by Marcos Farfan de los Godos, who visited the site in November 1598. Many believe this discovery was the oxidized cap of the United Verde ore body, which outcropped near the head of Verde Valley (Greeley, 1987). Unable to exploit this discovery, early Spanish explorers abandoned their find, but legends of fabulous riches persisted for nearly three centuries before prospectors rediscovered the rich copper ores of the Verde Mining District.

After exploring much of the province the Spanish named Pimeria Alta (i.e. northern Sonora and southern Arizona), Father Eusebio Francisco Kino, a Jesuit priest and skilled mapmaker, produced the region's first remotely accurate map in 1702. On this map, Kino identified a river entering the Gila River from the north as the Rio Azul (includes the modern day Verde and Salt Rivers). He named it after the legend of a mountain of gold, known as Sierra Azul (Ayers, 2010).

The first map that used the name Verde was published by Jesuit priest, Father Juan Bautista Nentvig in 1764. Incorporating information gleaned from travels of other Jesuit priests, Nentvig's map was the first to note the Rio Azul was actually composed of two rivers, one flowing from the northwest (Verde) and one from the east (Salado or Salt). The Salt River was named due to abundance of dissolved salt in its waters, while the Verde River was named for the presence of verdant groves of poplars along its banks (Ayers, 2010).

With the signing of the Treaty of Guadalupe Hidalgo at the end of the Mexican-American War on February 2, 1848, the United States acquired California, Nevada, Utah and portions of Colorado, Wyoming, New Mexico and Arizona (Greeley, 1987). Over the next two decades the Colorado River provided access to western Arizona, as far north as Parker, Arizona. From Parker, the Bill Williams and Santa Maria Rivers served as highways for prospectors, who were mainly searching for gold and silver (O'Brien, 1991).

Even if the early explorers recognized the presence of copper at these remote localities, there was little incentive for the lone prospector, because developing such discoveries required considerable amounts of infrastructure, manpower, time and expertise that could only be provided by a well-financed business

venture. On the other hand, gold and silver could be recovered by hand, transported out on a burro and sold for dollars per ounce, instead of a few cents a pound. By 1863, prospectors had reached central Arizona and discovered the Vulture Mine and rich placer gold deposits at Rich Hill near present day Wickenburg, Arizona.

On February 24, 1863, President Lincoln signed the Arizona Organic Act, which created the Arizona Territory, sub-dividing the New Mexico Territory into two territories along the present-day boundary. Fort Whipple was established at Del Rio Springs in Little Chino Valley on December 23, 1863 and served as Arizona's first territorial capital until May 30, 1864. On that date, both the capitol and military post were relocated to Prescott, which was close to placer gold discoveries that had been made along Lynx Creek the previous year (Figure 14).

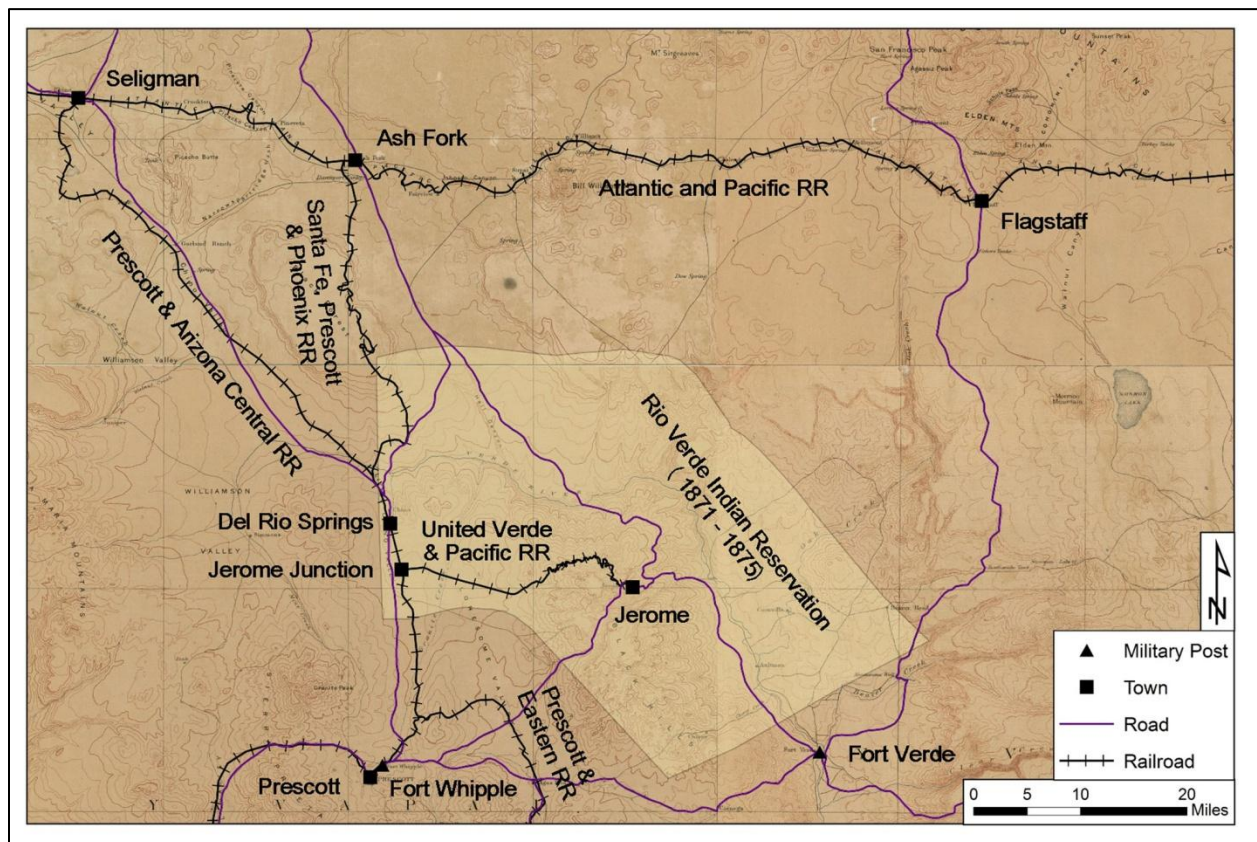


Figure 14. Historical map showing Rio Verde Indian Reservation, towns, military posts, roads and railroads during 1865-1900. [U.S. Geological Survey 1:250,000 Topographic Base Maps - Verde, Az. (1892), Prescott. Az. (1892), Chino, Az. (1891), San Francisco Mountain. Az. (1894)].

In January 1865, the first Anglo settlers arrived in the southern portion of the Verde River Valley, where they established farms that supplied produce to Prescott and nearby mining communities. During early years, life along the Verde River was harsh due to the presence of malaria that resulted from standing water impounded by numerous beaver dams along the river. However, the bottom lands were rich, allowing these early agricultural communities to prosper (McCarthy, 2014). As more settlers arrived in the region nomadic migration patterns of the Yavapai and Apache were disrupted. This competition for

resources often lead to conflicts between the two cultures. At the request of settlers, twenty soldiers were dispatched from Fort Whipple and established a small outpost to protect the farms along West Clear Creek in August 1865. This site became Camp Lincoln in December 1865 and was renamed Camp Verde in September 1866. The original site along West Clear Creek was subsequently abandoned after the military post was moved to its present location in April 1871.

Over the next six years, conflicts between the Anglo settlers and Native Americans continued to grow; prompting the Federal government to establish the Rio Verde Indian Reservation in October 1871 (Figure 14). This reservation was located on an 800 square mile tract that encompassed the upper Verde River Valley and adjacent mountain ranges. It included the future sites of Clarkdale, Cottonwood and Jerome. Over the next two years, troops under the command of General George Crook subdued the Indians, who were confined at the Rio Verde Indian Reservation (Braatz, 2003).

In December 1874, the Department of Indian Affairs decided to close the Rio Verde Indian Reservation and relocate the Yavapai and Tonto Apaches almost 200 miles southeast to the San Carlos Indian Reservation. Several factors prompted in this decision. First, the Federal government wished to reduce the number of Arizona reservations to make their administration more efficient. Second, government contractors based mainly out of Tucson were concerned that Indians on the Rio Verde Reservation were progressing toward agricultural self-sufficiency, thus reducing the need for their products. They lobbied to have the Rio Verde population relocated to the San Carlos Reservation, where farming conditions were less promising, resulting in an increase in the demand and more efficient distribution of the contractor's products. Finally, desirous of the fertile lands on the Rio Verde Reservation, many settlers in the region urged the Federal officials to close the reservation (Braatz, 2003).

In late February 1875, an estimated 1,500 members of Yavapai and Tonto Apache tribes were forced to relocate to the San Carlos Reservation in southeastern Arizona. More than 100 succumbed to combined hardships of hunger, exhaustion and exposure from this 180-mile journey during the harsh winter conditions. The Rio Verde Reservation was subsequently closed and the land was opened for settlement under the Homestead and Mining Acts.

### **United Verde - Rediscovery (1876 - 1888)**

John O'Dougherty, Edward O'Dougherty, A. B. O'Dougherty, John Boyd, John Kelley, and Josiah Riley located the first mining claims (Venture No. 1 South and Venture No. 1 North) in the Verde Mining District on February 17, 1876. Other early claims included the Azure Southwestern, Chrome Southwestern, Azure Northwestern, Chrome Northwestern and Gift claims (O'Brien, 1991).

In June 1876, Civil War veteran, Morris Ruffner, located the Eureka and Wade Hampton claims over a favorable copper-bearing outcrop that ultimately became the United Verde ore body (O'Brien, 1991). He drove a tunnel on this outcrop, which confirmed the presence of rich copper ore. Needing assistance to proceed further he enlisted the support of George and Angus McKinnon, who agreed to help work his holdings in exchange for a two thirds interest in his property. The partners sank a 45-foot shaft on the

Wade Hampton claim that encountered rich copper ore (Young, 1930). By late 1880, they realized they did not have the financial means to develop the property further and decided to sell their holdings.

In late December 1880, Dr. James Douglas visited the Verde Mining District at the request of J. P. Logan and Charles Lennig of Philadelphia, Pennsylvania, who had acquired an option to purchase the Eureka and Wade Hampton claims. Douglas was favorably impressed with the property's potential and encouraged the option be exercised, but cautioned they would not benefit from the investment until the Atlantic and Pacific Railroad had reached Ash Fork. Based on this advice, Logan and Lennig purchased the Eureka and Wade Hampton claims (Anonymous, 1981).

Construction of the western segment of the Atlantic and Pacific Railroad began at Isleta, New Mexico during the summer of 1880 and reached Lupton, Arizona on the Arizona-New Mexico state line in May 1881 and Ash Fork, Arizona in October 1882. It was completed to Needles, California, where it connected with a Southern Pacific branch line from Mojave, California in August 1883.

United Verde Copper Company Organized and Commences Operations. Frederick Tritle, a lawyer from Nevada arrived in Prescott, Arizona in December 1880. Appointed as Territorial Governor by President Chester Arthur in January 1882, Tritle held this office from March 8, 1882 until October 7, 1885.

Having experience in the mining industry, Tritle soon focused his attention on the recent discoveries in the Black Hills. With financial assistance from William B. Murray and Frederick F. Thomas, Tritle acquired options to purchase several of the more promising properties that adjoined the Wade Hampton and Eureka claims.

William Murray and Frederick Thomas journeyed east in late 1882 to acquire options on the Eureka and Wade Hampton claims and obtain financial backing for the project. Murray initially solicited funds from his uncle, Eugene Jerome, a wealthy New York banker and financier. Although Jerome was initially unwilling to finance the mining venture, his wife and her sister agreed to invest \$200,000 in the project. At that point, Eugene Jerome reluctantly agreed to take an active role in managing the business venture. Additional investors included James A. MacDonald, president of Queen's Insurance Company and Charles Lennig of Philadelphia (Rodda and Smith, 1990).

The United Verde Copper Company was incorporated under New York Law on February 23, 1883, with MacDonald as President and Jerome as Secretary-Treasurer. Fred Thomas, an experienced mining engineer with a degree from the Yale School of Mines became Superintendent and General Manager of the operation. The mining camp was named Jerome in honor of the Jerome family (Rodda and Smith, 1990).

With financing in place, the United Verde Copper Company began development of their holdings. This included the construction of two roads over which mule and ox teams transported supplies to this remote mining camp and copper was shipped to market. The first road was constructed southwestward over the mountain to a military/stage road that connected Prescott and Camp Verde (Figure 14). The second route was constructed northwestward from the mine to an existing road that connected Prescott and Ash Fork (O'Brien, 1991).

Mule and oxen teams transported a 36-inch water-jacketed blast furnace to the site from the rail head at Ash Fork. Smelting of the rich near-surface oxide ores began on August 1, 1883. With operating costs of 7 cents per pound of copper recovered, this operation produced both black copper (known as bullion), which averaged 94% copper, and a matte product that averaged approximately 60% copper. Freight costs over the 60-mile wagon road from Jerome to the rail head at Ash Fork were \$20/ton. Coke was used to fuel the smelter. It was purchased from a mine in New Mexico and delivered to Jerome via wagon on the return trip from Ash Fork at a cost of \$35 per ton. Rail shipping costs from Ash Fork to the Port Orford refinery in New Jersey were \$51.38 per ton, bringing the total transportation costs from Jerome to the refinery to \$71.38 per ton (Rickard, 1932).

Table 4. United Verde Copper Company operating data for 1883-1884 (Douglas, 1885).

Year	Ore Smelted Short Tons	Recovered Grade % Cu	Cu Lbs.	Ag Troy Oz.	Average Cu Price Cents/lb.	Dividends \$
1883	5,004	18.78	1,880,000	125,000	15.05	37,500
1884	12,067	14.58	3,518,000	160,092	13.85	60,000
Total	17,071	15.81	5,398,000	285,092		97,500

Despite these high transportation costs, the United Verde Company paid modest dividends of \$37,500 and \$60,000 for 1883 and 1884, respectively (Table 4). High-grade oxide ores were developed to a depth of approximately 160 feet with the underlying resource characterized by unoxidized sulfides. The operation recovered nearly 5.4 million pounds of copper and 285,000 ounces of silver before suspending operations on December 12, 1884. The shut down resulted from the exhaustion of much of the rich, near-surface, oxide ores and a decline in the price of copper to 11 cents per pound (Brogdon, 1952).

Prescott and Arizona Central Railroad. The first attempt to establish a railroad to Prescott, Arizona was made by the Central Arizona Railway, which was organized in May 1884. This effort was supported by the United Verde Copper Company and other mines of the region. Following the completion of the survey of the proposed route connecting Prescott with the Atlantic and Pacific Railroad, it was realized they lacked sufficient capital to build this line. About this time, two competing interests emerged. The first group formed a second Central Arizona Railway Company, which was led by Thomas S. Bullock, a local businessman, who represented a New York syndicate. The Arizona Central Railway was organized by a Minneapolis syndicate, headed by Nathan O. Murphy (Gilley, 1999). These firms merged in July 1885 to form the Prescott and Arizona Central Railway Company, which became known as the Bullock Line, after its president, Thomas Bullock. Construction of this standard gauge line began in July 1886 and was completed on December 31, 1886, connecting Prescott with the Atlantic and Pacific Railroad at Seligman, Arizona (Figure 14) (Anderson, 1936).

Second Attempt to Resume Production at United Verde Fails. Encouraged by the prospect of lower transportation costs resulting from the completion of the Prescott and Arizona Central Railroad to Prescott the previous December, Frederick Tritle acquired a lease on the United Verde property and resumed operations in July 1887. Using his own personal funds to finance the project, he erected a second blast furnace at the site. However, a combination of insufficient capital, poor management and

low copper prices (10.6 cents/lb.) doomed this business venture. Operations were suspended in September 1887 after Tritle failed to make the required lease payments (Brogdon, 1952). The United Verde property was placed on the market.

Phelps Dodge's First Attempt to Acquire the United Verde Property. This attracted the attention of several parties, who wished to buy the property. Among them was Dr. James Douglas, who now managed Phelps Dodge and Company's Arizona operations. After acquiring an option to purchase the United Verde property, Douglas and Ben Williams, the superintendent of the Bisbee operation, examined the site during late 1887. Impressed with the high grade oxide ores, the small size of this relatively undeveloped ore body raised concerns whether its projected development costs were warranted. They ultimately agreed Phelps Dodge and Company should acquire the United Verde property. Negotiations began in December 1887. Phelps Dodge and Company offered to pay off its outstanding debts that were estimated to be \$30,000 and agreed to spend up to \$200,000 on the development of the project, with the United Verde Copper Company receiving a small royalty on any future production (Anonymous, 1981).

Knowing other parties were keenly interested in acquiring the property, directors of the United Verde Copper Company made a counter proposal, which required Phelps Dodge and Company to purchase all of United Verde's outstanding stock for \$300,000. Having considerable capital already invested in their Bisbee and Morenci operations, executives of Phelps Dodge and Company ultimately decided not to purchase the United Verde property (Anonymous, 1981).

### **United Verde - William Andrews Clark (1888 - 1935)**

William Andrews Clark, the Man. William A. Clark was born in Connellsville, Pennsylvania in January 1839, where he lived on his family's farm until 1856, when his family moved to Van Buren County, Iowa. There he briefly taught school before entering an academy at Birmingham, Iowa and later attending Iowa Wesleyan University, where he studied law (Anonymous, 1930).

In 1862, Clark joined a wagon train and made his way to Central City, Colorado, where he worked in the gold mines during the winter of 1862-63, gaining a knowledge and experience in the mining industry. When news of gold discoveries at Bannock, Montana reached Central City during the spring of 1863, William Clark moved to Bannock, where he secured a mining claim along Horse Prairie Creek. After several years of placer mining, he formed a partnership in 1868, which engaged in the wholesale mercantile and banking business, located in Helena and Dear Lodge, Montana. After buying out his partners, Clark relocated this business to Butte, Montana (Anonymous, 1930).

Although successful in every endeavor he tried, William Clark devoted most of his interests to mining. After arriving in Butte, he acquired the Colusa, Original, Mountain Chief, Gambetta and other properties in 1872. Realizing he needed further technical training to develop his holdings, he attended the Colorado School of Mines, from which he graduated in one year (Brogdon, 1952). On returning to Butte,

he successfully developed his holdings, nearly all of which became major copper producers (Anonymous, 1930).

William Andrews Clark is a controversial figure in western history (Figure 15). During his lifetime, he built a vast business empire that in addition to his mining, banking and mercantile businesses also involved investments in public utilities, railroads, ranching and manufacturing industries (Anonymous, 1930). To some, Clark was one of the most powerful, influential and ruthless of the late 19th century American robber barons, rivaling better known figures such as Andrew Carnegie and John D. Rockefeller (Edgerton, 2014).

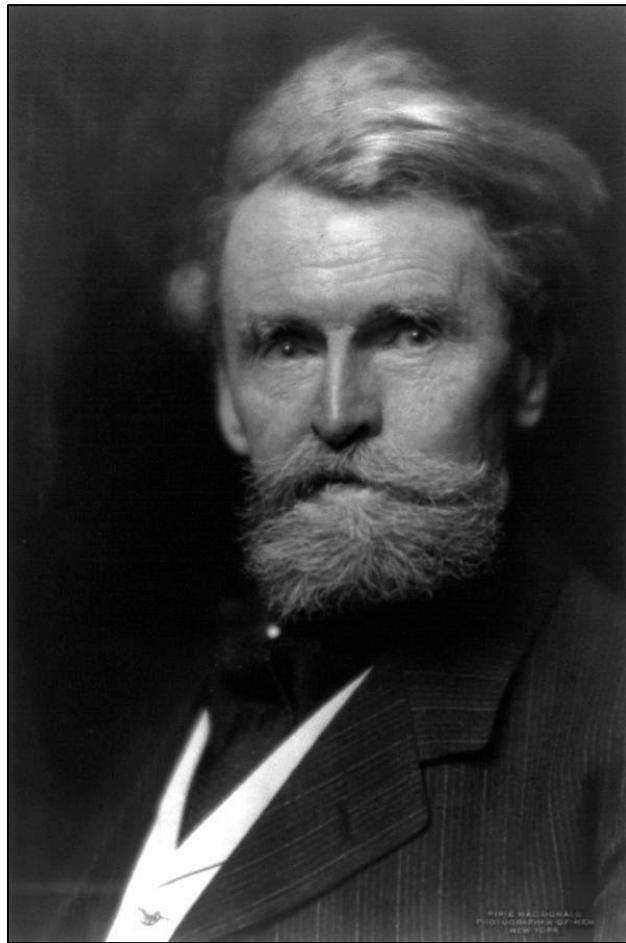


Figure 15. William A. Clark, President of the United Verde Copper Company from 1888-1925, was one of the most powerful, influential and ruthless of the American robber barons. Among his other accomplishments, Clark also served as a U. S. Senator from Montana from 1901-1907.

On the other hand, under the guidance of William Clark, the United Verde Copper Company made considerable efforts to make the lives of its workers better at this remote mining camp. Over the years, they erected four hospitals in Jerome, where miners received free medical and surgical care (Figure 16). The Montana Hotel opened its doors in 1900. Used to house the Jerome's miners, it was the largest stone structure in Arizona at the time, having 200 rooms and a dining hall that could accommodate 400

(O'Brien, 1991). United Verde also contributed more than \$17,000 for the construction of the Jerome high school in 1911 and erected a clubhouse at Jerome, which provided a large men's lounge containing pool and billiard tables, a ladies lounge, card room, soda fountain and a small ballroom (Greeley, 1987).

Clarkdale was one of Arizona's first planned communities. It was designed attract a more stable workforce by creating better housing conditions for United Verde Copper's workers and their families (Brogdon, 1952). This community included a clubhouse similar to one in Jerome, which included a bowling alley, theatre and an auditorium that also served as an opera house. Other recreational facilities included swimming pools, tennis courts, baseball and football fields and a golf course (Greeley, 1987).



Figure 16. Fourth hospital built in Jerome by the United Verde Copper Company was operated from 1927 until 1950. After remaining unused for 44 years, Phelps Dodge sold it to Larry Altherr, who refurbished the building, which became the Jerome Grand Hotel. Circa 2012 (photo provided by Jan Rasmussen).

Clark Acquires the United Verde Copper Company. By the mid-1880s, William Andrews Clark had already made a fortune from his investments in mining, banking and other business ventures. In 1884, he was appointed commissioner to represent the State of Montana at the 1885 Exposition in New Orleans. While there, he had an opportunity to examine a collection of rich copper ore specimens from the United Verde mine. These rich ore specimens intrigued him because of their reported high gold and silver values (Brogdon, 1952).

One of the customers for the copper matte produced at William Clark's Butte smelting operations was the Port Orford Copper Company. Following its bankruptcy in 1886, William Clark, who was one of its chief creditors, assumed control of Port Orford's New Jersey refinery and operated it for several years. This provided him an opportunity to examine its business records that included assays for ore shipments from the United Verde operation, which had exhibited ore specimens he had seen at the exposition in

New Orleans (Rickard, 1932). Upon learning the United Verde property was for sale, Clark dispatched his Montana mine superintendent, Joseph L. Giroux to Arizona (Brogdon, 1952).

By the time Giroux arrived in Arizona, he learned that Phelps Dodge and Company, represented by Dr. James Douglas, had already obtained an option on United Verde's Jerome holdings. He wisely arranged to have the right of first refusal should Phelps Dodge and Company decide not to exercise its option.

When negotiations with Phelps Dodge and Company broke down, William Clark acquired a two year purchase option for \$30,000 (Anonymous, 1888). Ratified by the stockholders of the United Verde Company in February 1888, Clark agreed to take over the development and operation of the mine in return for one-half of the operation's profits with the remainder of the profits going to the United Verde shareholders. Clark was wise to structure the deal in this manner. It gave him time to bring in experienced personnel from his other mining properties to evaluate and develop the United Verde holdings. Pending the outcome of this work, he could either exercise his option to purchase the United Verde Copper Company or walk away from it without investing much in the project (Rodda and Smith, 1990).

Production Resumes and Early Challenges Overcome. William Clark and his smelter supervisor, J. L. Thompson joined Joseph Giroux at Jerome in March 1888 and began reviewing all aspects of the United Verde operation. Using two 50-inch cylindrical, water-jacketed, blast furnaces, smelting operations resumed on May 22, 1888 (Richard, 1987).

Upon arriving in Jerome, Clark realized he faced many challenges. At that time the mining camp was little more than a collection of make-shift and hastily constructed dwellings perched high on the steep northeast slope of the Black Hills, overlooking the Verde River Valley. Roads connecting Jerome to the outside world were in poor condition. Freight charges to and from the Prescott and Arizona Central rail head were relatively high at \$9.00 per ton (Smith and Sirdevan, 1922). Working conditions at this remote site were poor. Harsh weather during winter months commonly brought operations to a standstill. The mine required considerable development before efficient operations could be resumed. Much of the high-grade, near-surface, oxide ores had been mined previously; leaving less amenable copper sulfides. However, Clark was confident his experience smelting sulfide ores at Butte would help him to solve this problem (Tenney, 1927).

Despite these hardships, Clark used his share of the profits derived from the sale of matte to develop the United Verde mine, confirming the presence of a major sulfide ore body that assayed 10 to 20% copper. These efforts benefited from relatively high copper prices (averaged 15.2 cents/lb.) during 1888 and 1889. On January 9, 1890, William Clark exercised his option to purchase the United Verde Copper Company; acquiring 285,821 shares (95.3%) of its stock. The reported purchase price was \$275,000 (Ascarza, 2014). James McDonald, the company's first president, was the only partner, who did not sell out to Clark (O'Brien, 1991). The United Verde Copper Company was similar to all enterprises with which Clark was associated. Not a single share nor bond issue by any one of them was either listed, quoted, or could be purchased on any stock exchange in the United States (Brogdon, 1952).

Under the first several years of Clark's management, the existing shaft (No. 1) was sunk to a depth of 500 feet with levels developed on 100-foot intervals, encountering considerable ore (Anderson and Creasey, 1958). The ores from the upper levels of the mine were extracted from large stopes that required the use of square-set-and-fill mining methods, which were ideally suited for the soft, heavy and broken rock in these areas (Tally, 1917). A 1,200-foot access/drainage tunnel, connecting workings on the 500-foot level of the mine with surface facilities, was completed in December 1892 (Tenney, 1927). Following the abandonment of the No. 1 Shaft due to unstable ground in 1894, the 500-foot level tunnel provided the sole access to mine until a raise (No. 2 shaft) was completed to the surface during the summer of 1901 (Stevens, 1902).

When the decision was made to replace the existing smelter, it was decided to locate the new smelter in a gulch that had been filled in with debris from early mining operations. The plant site was graded off on the 50-foot level (also known as the "Slag Level") and the new smelter with its related shops and offices were built directly over the ore body, which covered an area measuring 800 feet by 1,000 feet (Alenius, 1968). Engineering studies concluded the square-set-and-fill mining methods used at United Verde would provide sufficient support to prevent significant settling at the surface (Tally, 1917). This decision would ultimately cause problems that plagued the operation over the next several decades.

Replacement of the existing smelter began during 1891 with the construction of a 160-ton, 48-inch by 120-inch, blast furnace, which was commissioned in April 1892. A second blast furnace of similar capacity and Bessemer converters were added to the facility during 1894. These blast furnaces were expanded to 48-inches by 240-inches during 1895 (Rickard, 1987). Designed to treat flue dust and ores containing high gold and silver values, Jerome's first reverberatory furnace was commissioned in 1896 (Tenney, 1927). By 1899, the addition of a third blast furnace increased United Verde's smelting capacity to approximately 1,000 tons per day.

The United Verde Copper Company paid its first dividend under Clark's management in 1892 on the basis of 25 cents per share per month (Stevens, 1904). The increased production capacity established during the 1890s enabled the United Verde operation to increase its annual copper output from 7.4 million pounds in 1891 to nearly 44 million pounds in 1899, making its Arizona's largest copper producer (Tenney, 1927).

Heap Roasting of Sulfide Ores. Commencing in 1894, early smelting practices at United Verde involved delivering all of the higher grade ores directly to the smelter, while low-grade ores were transported to a surface roasting facility located at the head of a drainage adjacent to the entrance of the 500-foot level tunnel, immediately north of the mine (McCarthy, 2014). These low-grade ores were stacked in 500-ton heaps and roasted with cordwood, derived from the slopes of surrounding mountains (Figure 17). Following five to nine weeks of roasting, the calcine product was delivered to the smelter. Both ore and calcine handling logistics were improved with the commissioning of the No. 2 shaft during the summer of 1901, providing a more efficient means of transporting ore and calcine from the mine to the smelter.



Figure 17. Heap roasting at the United Verde operation, circa 1900 (Anonymous, 1911).

The use of timber harvested from public lands in the roasting of copper ores at United Verde's operation resulted in a case heard by the U. S. Supreme Court (*United States vs United Verde Copper Company*) in December 1904. At that time, U. S. law permitted timber harvested on federal lands in Arizona to be used for "building, agricultural, mining and other domestic purposes". However, its use in smelting operations was specifically prohibited by Department of Interior (DOI) regulations, that administered U.S. law. Finding in favor of the defendant in January 1905, the U. S. Supreme Court found the United Verde Copper Company had violated no laws by deciding roasting was a part of the mining process, distinguishing it from smelting. Furthermore, by the incorporation of the phrase "other domestic purposes", the Court found Congress did not intend its legislation to apply to only those uses specifically enumerated by the act, which nullified DOI regulations that denied its use by smelting operations (Anonymous, 2017a).

Santa Fe, Prescott and Phoenix Railroad. From its completion in late December 1886, the Prescott and Arizona Central Railroad experienced numerous difficulties. Poorly constructed and managed, its roadbeds and equipment were in a constant state of disrepair. Shipments were almost always late because it was unable to meet the posted schedules. Without a turntable in Prescott, trains also had to back all of the way on their return trip to Seligman (Gilley, 1999).

Over the next several years, the United Verde Copper Company urged the Prescott and Arizona Central Railroad to construct a branch line to Jerome, but little was done to relieve its high transportation costs.

To accommodate its major customer, the Prescott and Arizona Central Railroad proposed construction of a 4.85-mile aerial tramway in 1890. Extending from the mouth of Yeager Canyon over the Black Hills to the United Verde mine, this tramway was designed to use buckets that were capable of carrying 300 pounds each. Construction began during the spring of 1892, but quickly encountered a number of technical problems and was never completed. In any event, this feeble attempt to meet the demands of its customers in Jerome was a case of too little, too late for the Prescott and Arizona Central Railroad (Trennert, 1999).

After enduring five years of poor service, residents of Prescott persuaded executives of the Atlantic and Pacific Railroad to form the Santa Fe, Prescott and Phoenix Railway Company in May 1891 (Gilley, 1999). The proposed route for this new standard-gauge line ran from the Atlantic and Pacific's railhead at Ash Fork to Prescott and continued southeast to Phoenix via Wickenburg. Construction began on August 17, 1892 (Figure 14). With the arrival of the first trains in Prescott on April 25, 1893, business rapidly declined for the Prescott and Arizona Central Railroad, which was subsequently abandoned (Irvin, 1987). The Santa Fe, Prescott and Phoenix Railroad was completed to Phoenix on February 28, 1895, at a total cost of nearly \$5 million (Gilley, 1999).

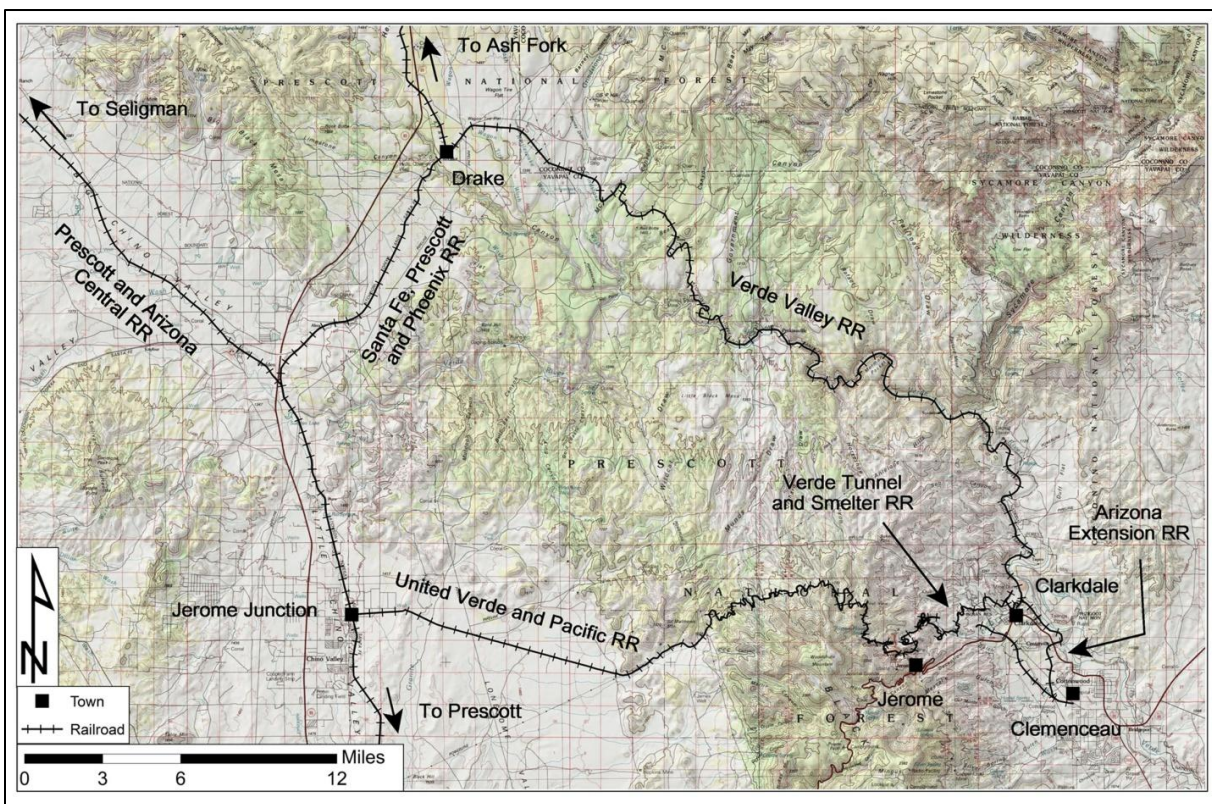


Figure 18. The Verde Mining District was served by four railroads. The United Verde and Pacific Railroad (1895-1920) and the Verde Valley Railroad (1912-1992) provided access to the Santa Fe, Prescott and Phoenix Railroad, which connected with the Atlantic and Pacific Railroad (later Santa Fe) at Ash Fork, Arizona. The Verde Tunnel and Smelter Railroad (1915-1953) and Arizona Extension Railroad (1918-1938) connected the United Verde and U VX mines and smelting facilities at Clarkdale and Clemenceau, respectively (U.S. Geological Survey, 1:100,000 scale topographic map).

United Verde and Pacific Railroad Arrives in Jerome. Upon completion of the Santa Fe, Prescott and Phoenix Railroad to Prescott, William Clark laid plans to construct the United Verde and Pacific Railroad from a rail head in Little Chino Valley to Jerome (Figure 18). Grading of this 28-mile narrow gauge line began in June 1894. The rail line was completed on January 24, 1895. Traversing rough mountainous terrain, the United Verde Pacific Railroad was known as the "most crooked railroad in the world" (Irvin, 1987).

The western terminus of the United Verde and Pacific Railroad was at Jerome Junction (now known as Chino Valley), where there was a roundhouse, turning wye, facilities to transfer loads from narrow to standard gauge rolling stock, livestock corals, water tanks, warehouses and station platform that served both lines (Figure 18). The community of Jerome Junction had housing for workers, a hotel, two saloons and a school that served as a church on Sundays (Anonymous, 2017b).

The eastern terminus of the United Verde and Pacific Railroad was at the Jerome mine site, where there were a number of sidings and spurs, a turntable, storage bins for ore, lime, coke and coal, smelter and railroad offices, warehouses, machine shop, and a freight depot. Infrastructure on a lower level of the mine site were accessed by an 800-foot incline, where a steam-powered hoist was employed transfer rail cars from the main rail line to the lower level (Anonymous, 2017b).

Business opportunities resulting from the rapid expansion of the United Verde operation during the 1890s attracted many to venture to Jerome; population grew 10-fold from 250 in 1890 to 2,861 in 1900. The arrival of the United Verde and Pacific Railroad in Jerome in January 1895 spurred this growth, significantly lowering the cost of transporting goods to and from this remote site. This railroad benefitted both the United Verde Copper Company and businesses that provided goods and services to the mine and its workers. Following three disastrous fires that swept through Jerome between December 1897 and May 1899, residents rebuilt their community with substantial concrete and brick structures, including its second hospital in 1899. When Jerome was incorporated on March 9, 1899, it was the fourth largest city in the Arizona Territory, behind Tucson, Phoenix and Prescott (O'Brien, 1991).

Mine Fires and Unstable Ground Plague the United Verde Operation. During the fall of 1894, the United Verde mine experienced its first major underground mine fire. It began in the Hampton stope following a serious cave-in on the 300-foot level (Tally, 1917). When exposed to air, strongly broken, massive pyritic ores at United Verde were easily oxidized. Heat (1,200 degrees F.) generated during the oxidation process in poorly ventilated areas was sufficient to result in spontaneous combustion of the timber used to support the stopes (O'Brien, 1991). Unable to be extinguished, the 1894 fire was isolated from the remainder of the mine by a series of strategically placed concrete bulkheads. However, the soft, broken nature of the ground was such that smoke and gas permeated several levels, preventing mining activities over a much larger area.

Although the first mine fire caused few difficulties at the time, it and later fires that spread throughout the upper levels of the United Verde mine made operations increasingly more difficult. The first serious problems were experienced on October 7, 1900, when subsidence from a large cave-in resulted in \$100,000 in damage to the smelter. In August 1902, another fire on the 500-foot level resulted in

suspension of all mining and smelting operations from September 1902 until January 1903. In April 1905, run-off from heavy spring rains seeped down into the burning stopes on the 700-foot level and caused an explosion, killing five miners. Caving ground that followed this explosion damaged the smelter foundations and rail line near the freight depot (Tenney, 1927). By 1907, mine fires denied access to 75% of United Verde's developed reserves (Tally, 1932). Completed to a depth of 700 feet during the summer of 1901, the No. 2 shaft was later deepened to 1,000 feet, before it was abandoned in 1909 due to a fire on the 250-foot level (Mills, 1934).

Over the years various attempts were made to extinguish the mine fires, using water, carbon dioxide gas and steam. Each attempt failed because the burning area was unable to be sealed due to the highly fractured nature of the ground, which allowed sufficient air to feed the fire. The Plenum system was introduced at United Verde in 1905. Developed by Joseph Shaw, it is a type of ventilation system where air is pumped into a burning stope at a pressure slightly greater than the gases released by the fire, forcing the hot gases upward to the surface through an upcast air raise (Tally, 1917). This system successfully extinguished some of the underground mine fires at United Verde, gradually lowering the temperature in affected stopes to a level that mining could safely resume. Although successful, the Plenum system was expensive, inefficient, hazardous, and difficult to implement (Tally, 1932). In spite of this, United Verde continued to show a profit due to the high grade of its ores.

From the miner's perspective, working conditions at United Verde's underground operation were quite harsh. Mine workings were very hot and contained acidic waters that caused blisters and sores on unprotected skin. Sulfur dioxide and hydrogen sulfide gases also posed significant problems. Mine fires, dust explosions, and unstable ground made underground work very hazardous (Stevens, 1904). Between 1893 and 1916, sixty fatalities were reported at the United Verde operation, including six deaths during 1900, eleven in 1905, and 13 in 1907 (Dorich, 1997).

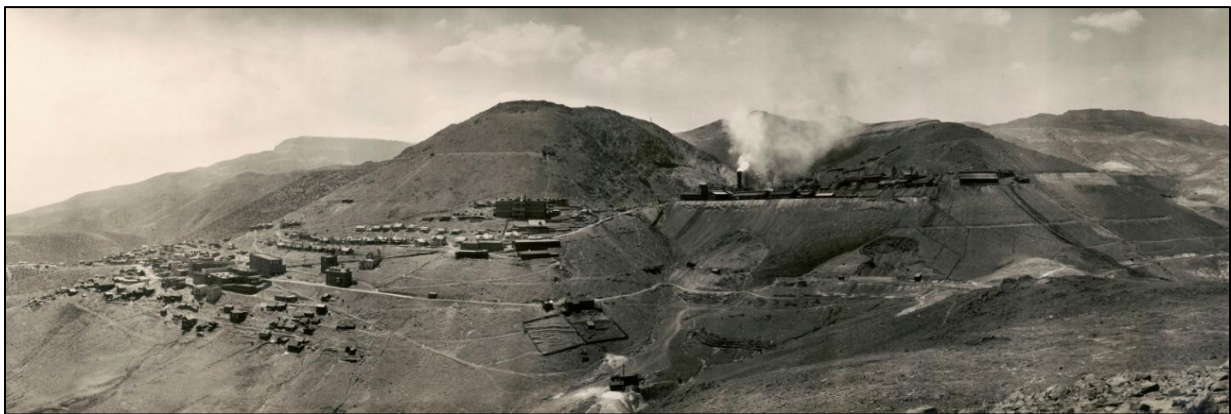


Figure 19. Panorama of Jerome town site and United Verde mine, looking southwest - circa 1909 (photo provided by Library of Congress).

Life in the Jerome Mining Camp. At the beginning of the twentieth century, Jerome was a vibrant community, consisting of three churches, a school, six hotels, a dozen saloons, a bank, three newspapers, a red-light district, opium dens, and numerous mercantile and service-related businesses

(Figure 19). The water supply for Jerome was piped from Walnut Springs and stored in large water tanks on the hill above the smelter and town (Brogdon, 1952).

Like many western mining camps of the time, Jerome's population was characterized by a diverse group of nationalities. During the early 1900s, Jerome had Chinese, Irish, and Italian communities with individuals of Slavic origin making up the largest ethnic minority until World War I. By that time a large number of Mexican nationals began to arrive, establishing an enclave below the main part of town to the north and east. The United Verde Copper Company employed workers of twenty-three nationalities in 1920 (Clements, 2003).

Life in Jerome was not without its challenges. Perched on a steep mountain side, drainage was always a major problem as intermittent cloudbursts swept mud and rock down from mountainsides that had been deforested by years of overharvesting of trees to heat the homes of Jerome's residents and fuel roasting operations. Toxic emissions from roasting and smelting operations inhibited growth of new vegetation, compounding this problem. Lacking an adequate sewage treatment system, sanitary conditions in Jerome were poor, exposing its residents to typhoid fever and other diseases (O'Brien, 1991). Uncontained sulfur dioxide fumes released by United Verde's smelting and roasting operations produced a gagging stench that enveloped the town and surrounding area (O'Brien, 1991). Upon reacting with moisture, it produced a weak sulfuric acid solution that damaged crops and caused respiratory ailments in many of Jerome's residents.



Figure 20. Panorama of United Verde Copper Company smelter at Jerome, looking northeast - circa 1909 (photo provided by Library of Congress).

Mining and Smelting Operations during the Early 20<sup>th</sup> Century. The capacity of the smelter was expanded to 1,750-tons per day during 1903 (Figure 20). This facility included one 250-ton blast furnace, three 500-ton blast furnaces and a reverberatory furnace for treating flue-dust, fines and ores, containing high precious metal values. There were six converters and a small tilting furnace for casting anodes. Production costs for 1904 through 1907 were 9.17, 9.27, 8.69 and 10.54 cents per pound of

copper recovered, respectively (Stevens, 1911). The practice of heap roasting was discontinued around 1909 (?).

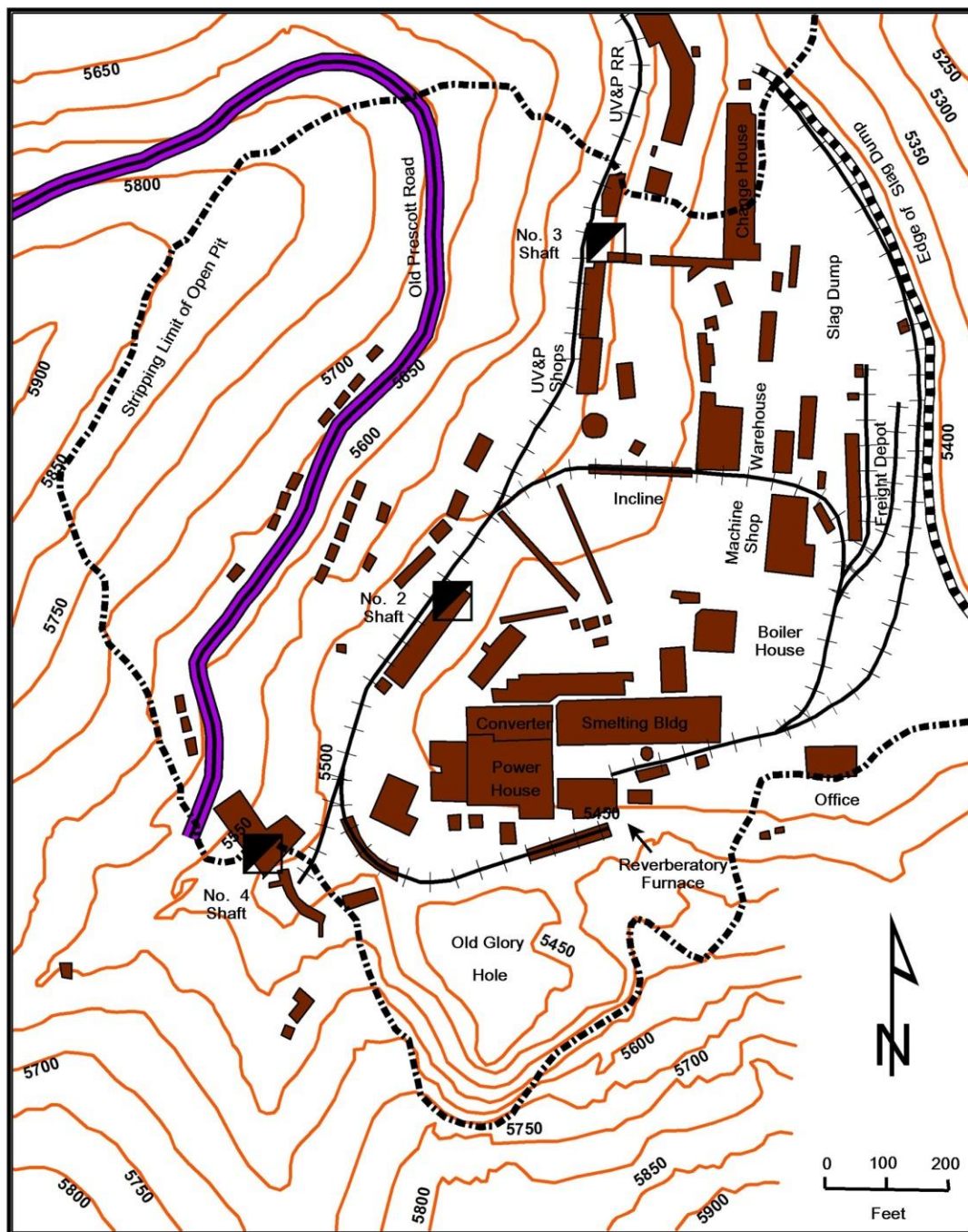


Figure 21. Topographic contour map showing layout of the United Verde surface plant and smelter prior to commencement of open pit operations (modified from Alenius, 1930).

As early as July 1907, the management of the United Verde Copper Company realized major changes to its operations were necessary if the mine was to remain profitable (Brogdon, 1952). Located above the

ore body, there was little room to expand the existing smelting facility, which had become congested in the tight confines of a short box canyon (Figure 21). Maintenance costs for these existing facilities had become excessive do to local subsidence. Not only would the reserves contained within the burning stopes be required to maintain production, but development of additional reserves would be necessary to justify the capital investment of building a new smelter. An aggressive three-year exploration campaign identified 10.5 million tons of ore (reserves as of January 1, 1911) on all levels from the surface to the lowest level (1,000-foot) of the mine (Tally, 1932).

Over the next decade, new mining practices and methods were implemented to minimize impacts resulting from mine fires. Square-set-and-fill mining methods were employed at the United Verde operation prior to 1908. Since then, the use of timber in stopes was minimized by employing horizontal cut-and-fill mining methods, when feasible. Main hoisting shafts were constructed with concrete or other fire-proof material. Use of high-sulfide material as backfill in timbered stopes was discontinued. Careful attention was also directed toward ventilation of the mine, which dissipated the buildup of heat from oxidizing sulfides and thus reduced the potential for spontaneous combustion (Tally, 1917). Ultimately, the decision to relocate the smelter provided United Verde Copper an effective way to deal with the underground mine fires by extracting much of the burning ores by open pit methods.

Excavation of the 6,593-foot Hopewell drainage tunnel began on December 23, 1906 and was completed on September 10, 1908. Measuring 7-feet by 9-feet, this tunnel was designed to drain water from mine workings above the 1,000-foot level (elevation - 4,525 feet) of the United Verde mine. Copper-bearing waters from the mine were treated by a precipitation plant, where copper was plated onto scrap iron (Stevens, 1911).

The search for a new smelter site began during 1910. An ideal location along the southern bank of the Verde River was ultimately selected in June 1911 (Brogdon, 1952). It had an adequate water supply, good drainage, ample sand and gravel deposits for construction materials, and a fairly large deposit of clay that was suitable for making bricks. It was accessible to the proposed Verde Valley Railroad and was close to suitable slag and tailings disposal sites. Room was also available for expansion of the plant and adjacent town site (Lanning, 1930).

Verde Valley Railroad. Knowing transportation was the key to the success of a project of this magnitude, William Clark entered an agreement with the Santa Fe, Prescott and Phoenix Railroad to finance the construction of the Verde Valley Railroad from Drake to the future site of Clarkdale (Figure 18). Construction of this 38-mile standard gauge line began in October 1911 and was completed to Clarkdale in November 1912 at a cost of \$3.5 million (Brogdon, 1952). Unlike the United Verde and Pacific Railroad that had been in operation since 1895, this rail line did not require the manual transfer of freight at narrow/standard gauge transfer points. Verde Valley farmers also benefited from the construction of the Verde Valley Railroad, which provided them affordable access to half a dozen nearby markets for their produce (Brodgon, 1952).

Verde Tunnel and Smelter Railroad. Requiring a rail connection between the mine and the new smelter, William Clark incorporated the Verde Tunnel and Smelter Railway on August 10, 1912 (Irvin, 1987). This

standard gauge line initially ran from the portal of the Hopewell tunnel, where ore from the mine was transferred to 40-ton bottom-dump railroad cars for transport to the Clarkdale smelter (Figure 22). Grading began in January 1913 and the rail line was completed in February 1915.

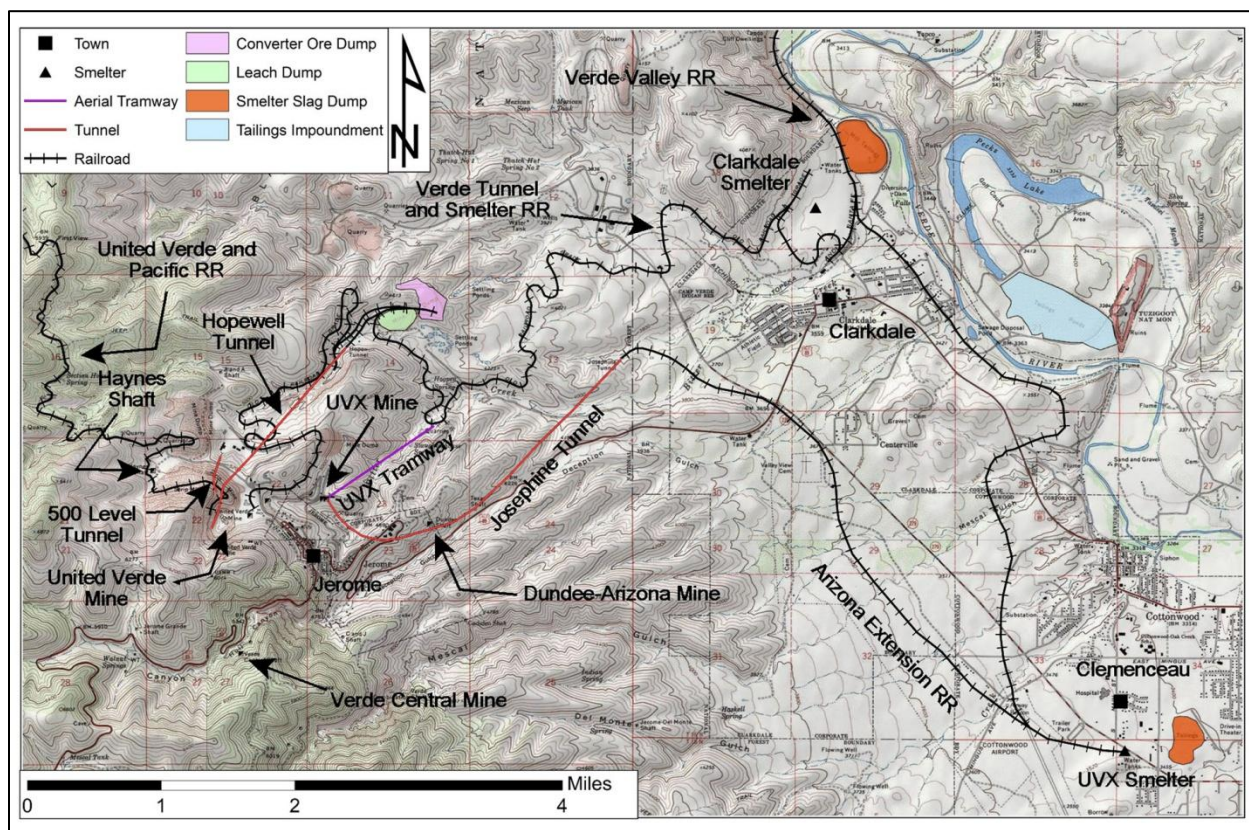


Figure 22. District map showing towns, major mines, smelters, railroads and mine infrastructure (U. S. Geological Survey 1:24,000 topographic map).

Once the decision to mine the shallow ore by open pit methods was made, work began on plans to extend the Verde Tunnel and Smelter Railroad to a new terminal located at the mine site. Construction of this section commenced in January 1918 and was completed in January 1920. Having a continuous gradient of 4% over its entire length of 11 miles, this line rose from an elevation of 3,460 feet at Clarkdale to approximately 5,200 feet at Jerome. Following the completion of the standard gauge line to Jerome, the United Verde and Pacific Railroad was abandoned. Its track and rolling stock were sold to the United Commercial Company of California on April 28, 1920 and subsequently dismantled (Brogdon, 1952).

Clarkdale, One of Arizona's First Planned Communities. The United Verde Copper Company designed Clarkdale to house employees of its mine and new smelting facility. This community was planned in every detail and was a model of symmetry. Spanish colonial style architecture dominated the town center and business district. No lots were sold, but were leased. Amenities included general stores, banks, drug stores, a post office, theater, bakeries, restaurants, hotels and office buildings. Several hundred, three to seven-room brick houses were constructed to be rented to United Verde's workers.

Modern public utilities included telephone, telegraph, electric, sewer and spring water services (Brodgon, 1952).

Like most mining communities of the early 20<sup>th</sup> century, Clarkdale was segregated along ethnic lines. Mexicans and Mexican American laborers lived in Patio Town, located across Bitter Creek between the train depot and the Verde River. Engineers, executives and other white collar workers lived in Upper Clarkdale, while Lower Clarkdale was reserved for the working class (Anonymous, 2017c).

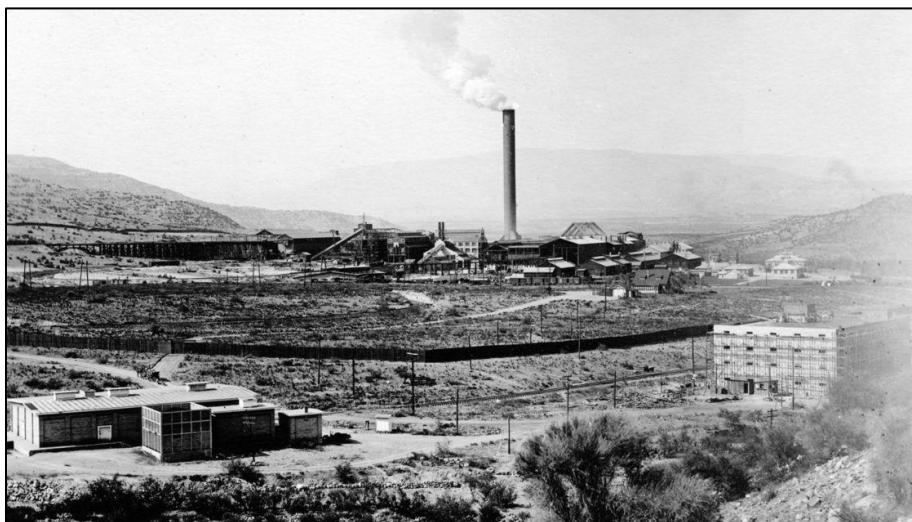


Figure 23. Clarkdale smelter. circa 1915-1920 (photo provided by Freeport-McMoRan, Inc.).

United Verde Copper's Clarkdale Smelter. The firm of Repath and McGregor of Douglas, Arizona was commissioned to design and build the new smelter (Figure 23). Engineering on the new facility began in 1911. Ground was broken at the new site in September 1912 and the first steel was erected in May 1913. The first blast furnace at this 2,500-ton/day facility was commissioned on May 26, 1915.

This smelter included six Wedge roasting furnaces, three 19- by 101-foot reverberatory furnaces, four 48- by 320-inch blast furnaces and four 12-foot diameter Great Falls converters (Vail, 1913). At the time it was erected, United Verde's 400-foot steel stack was reported to be the world's tallest steel stack (Anonymous, 1918a). The older smelter at Jerome was closed on August 28, 1915 and subsequently dismantled. Once cleared, excavation of the open pit began.

A crushing plant was erected adjacent to the portal of the Hopewell tunnel in 1916 to provide storage of crushed ore ahead of the sampling plant located at the smelter (Lanning, 1930). The increased capacity of this modern facility allowed United Verde to increase production from 32.5 million pounds in 1914 to 77.5 million pounds in 1918 (DeWitt and Waegli, 1989).

Labor Unrest during World War I. With the price of copper steadily rising as a result of World War I, the United Verde Copper Company voluntarily implemented a sliding wage scale for its workers during 1916, granting an increase of 25 cents per day for each 3 cents increase in the price of copper. Daily wages were \$3.75 when copper averaged 17 cents or less, \$4.00 when it averaged between 17 and 20 cents

and so on. Daily wages peaked at \$5.00 in December 1916. This effort to stave off labor unrest ultimately failed as the price of copper fell during the spring of 1917. On May 24, 1917, the local shop of the International Union of Mine, Mill and Smelter Workers called a strike demanding Miami-scale wages (\$5.25/day), a closed shop, and the establishment of a grievance committee. This dispute was settled on June 4, 1917 with the miners securing the Miami wage scale and a grievance committee (Brogdon, 1952).

New labor problems arose on July 6, 1917, when an affiliate of the International Workers of the World (I.W.W. or Wobblies) called for a strike, demanding a six-hour work day, \$6.00/day daily wage and other concessions. Charles Moyer, the president of International Union of Mine, Mill and Smelter Workers, the dominant union in the district, advised its members to ignore its rival and continue working. However, the I.W.W. implemented a campaign of fear and intimidation, which adversely impacted the district's mining operations. Everything came to a head on July 10, 1917, when citizens of Jerome, including many miners, rounded up 67 of the trouble makers, marched them up the hill to a waiting train and loaded them into two cattle cars. The agitators were transported under armed guard to a desert area outside of Needles, California, where they were abandoned and told not to return to Jerome. Known as the "Jerome Deportation", this event preceded the better known "Bisbee Deportation" by two days (Brogdon, 1952).

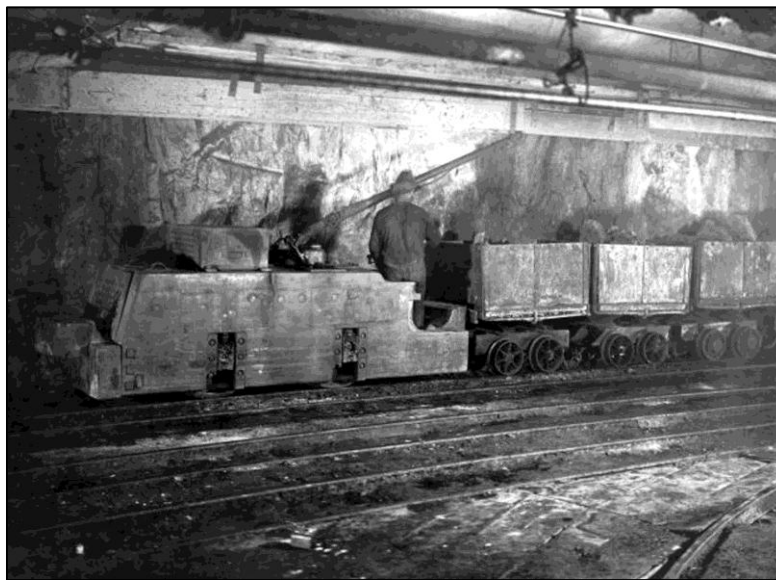


Figure 24. Electric locomotive on 1,800-foot level of the United Verde mine (photo provided by Freeport-McMoRan, Inc.).

Underground Operations at United Verde. With the relocation of the smelting facilities to Clarkdale, the Hopewell tunnel was modified to serve as the main ore haulage tunnel. Ore from the lower levels of the mine were transported by small electric locomotives to strategically located ore bins adjacent to the No. 5 shaft from which it was hoisted and dumped in the main ore storage bins located above the 1,000-foot main haulage level (Figure 24). All broken ore from stopes above the 1,000-foot level was dumped

into transfer raises, which were connected to the main ore storage bins, located above the 1,000-foot main haulage level.

Forty-ton, bottom-dump ore cars were loaded from main ore bins located above the 1,000-foot level and trammed by 25-ton, standard gauge, trolley-type locomotives to the crushing plant located near the portal of the Hopewell tunnel (Figure 25). The crushed ore was delivered to the Clarkdale smelter via the Verde Tunnel and Smelter Railroad (Smith and Sirdevan, 1922).



Figure 25. Trolley-type locomotive hauling ore from the Hopewell tunnel (Photo provided by Freeport-McMoRan, Inc.).

Development Open Pit Operations at United Verde. In preparation for beginning open pit operations, stoping operations in the upper levels of the underground mine were suspended during 1916 (Mills, 1934). Open pit operations proceeded in two stages, each employing different methods and equipment, while underground operations continued in lower levels of the mine. Mining above the 160-foot level (base of the oxidized zone) mainly involved stripping of waste and mining of oxide ores in the "upper pit". Extraction of sulfide ores was confined to the "lower pit" below the 160-foot level (Alenius, 1930).

Early stages in development of the open pit operation included excavation of the hill adjacent to the 500-foot level portal to make room for machine shops, power plant, change house and mine offices (Tenney, 1927). During the fall of 1918, stripping operations began in the "upper pit" with the removal of 1.6 million cubic yards of slag from the entrance and floor of the box canyon, where the ore body apexed (Alenius, 1930). An 8-cubic yard, Marion 300 steam shovel began excavating the 160-foot level of the slag dump, while a 4-cubic yard Osgood Model 120 railroad type steam shovel worked on the 300-foot level. A series of switchbacks designed for a standard gauge railroad were constructed on the north side of the steep ridge that formed the hanging wall of the ore body. These switchbacks provided access to the south side of the ridge, where benches were established along the north side of the planned pit

(Alenius, 1968). Following the completion of the Verde Tunnel and Smelter Railroad in January 1920, stripping commenced on the intermediate levels of the northwest side of the pit. A new surface plant was completed on the 500-foot level during 1920. It included an air compressor plant, machine shop, boiler shop, blacksmith shop, change house, drill sharpening shop, timber handling plant and other facilities (Kruse, 1930). Early stripping operations also resulted in the abandonment of the No. 3 and No. 4 shafts during 1921 (Mills, 1934).

1918 Spanish Flu Epidemic. The 1918 Spanish flu epidemic struck the mining communities of Jerome, Clarkdale and Verde (renamed Clemeneau in 1920) in late September 1918. Initial efforts to control the spread of the disease included a ban on public gatherings, closure of public schools, cancelation of church services, and isolating the sick in a separate ward of the hospitals. Eventually, Yavapai county officials placed the communities of Jerome, Clarkdale, Cottondale and Verde under quarantine in mid-October 1918. No one could leave or enter without a special permit. By mid-November 1918, the worse was over and quarantine lifted, but precautions against further spread of the disease continued until the spring of 1919 (Peterson, 2009).

Overall, there were approximately 1,500 reported cases of the flu in the area with approximately 60 fatalities. Although fatality rates of those infected in the upper Verde Valley communities were similar to the national average, infection rates (7.5%) were well below those observed worldwide (33%). This has been attributed to mining camp's remote location, which allowed authorities to implement a more effective quarantine. Furthermore, the few local companies that dominated the area had firm control over their employees making it easier to enforce regulations. Modern hospitals staffed by competent doctors also contributed to the lower infection rates (Peterson, 2009).

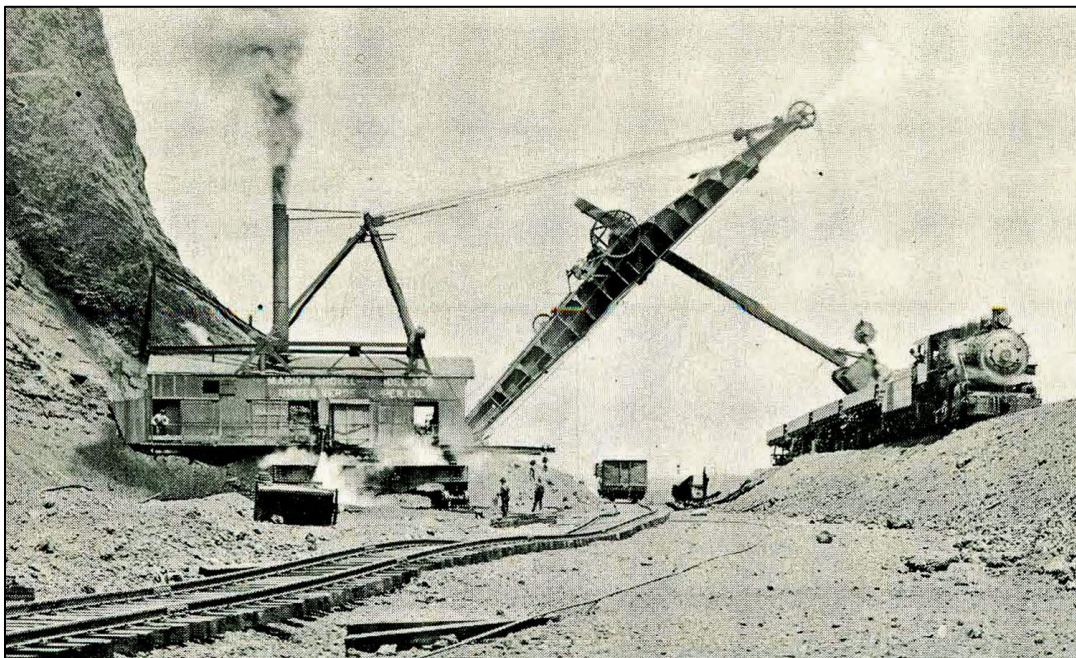


Figure 26. Rail-mounted Marion 300, 8-cubic yd., coal-fired steam shovel stripping slag on the 160-foot level of the United Verde mine - circa 1920 (Alenius, 1968).

Open Pit Operations at United Verde. Following the end of World War I in November 1918, copper prices fell from 26 cents to 12.4 cents per pound, resulting in the suspension of all mining and smelting operations at United Verde on May 1, 1921 (Tenney, 1927). When operations resumed on June 1, 1922, equipment employed in the upper levels of the open pit included two 4-cubic yard railroad-type steam shovels (later converted to track mounted) and a single 3/4-cubic yard steam shovel that was used to excavate switchbacks and roads. The 8-cubic yard shovel continued to remove slag on the 160-foot level (Figure 26). Rail haulage was performed by seven steam-powered locomotives and thirty 25-ton, air-dump rail cars. Initially powered with coal, both the steam shovels and locomotives were later converted to burn less expensive oil (Alenius, 1930).

Waste from the open pit operations was transported via rail to dumps strategically located adjacent to the switchbacks. Low-grade oxide ores from the open pit were hauled via rail to a dump leach facility constructed near the portal of the Hopewell tunnel. Commissioned in August 1922, copper-bearing solutions from the dump leach pads were treated at the existing Hopewell precipitate plant, where copper was plated onto scrap iron.

By December 1923, stripping operations exposed the upper portion of the sulfide ore body on the 160-foot level. Initial attempts to mine this material employed glory-hole mining methods (Alenius, 1930). Glory hole mining is a type of open cut mining where the ore is removed by gravity through steep funnel-shaped ore passes developed within the ore body that connect to underground workings from which it is trammed to the surface on the haulage level. However, this method did not prove practical due to spatial distribution of the underground fires and existing stopes, dilution of the ores, inability to sort the different ore types, and hazardous operating conditions (Alenius, 1930).



Figure 27. Ten-ton side-dump haul truck dumps ore in a transfer raise that is connected to underground ore storage bins located above 1,000-foot haulage level. Circa late 1920s (Alenius, 1968).

In March 1925, it was decided to modify mining operations in the "lower pit", which was mined on 25 to 33-foot benches with four 1.75-cubic yard, track-mounted, Bucyrus-Erie 50-B electric shovels, eleven 10-ton, conventional, haul trucks, six 10-ton Lin tractor, haul trucks(2 front wheels and caterpillar tracks on rear) and auxiliary equipment. The small shovels helped maximize the operation's flexibility and were able to sort the different types of material very well. The ores were hauled by side-dump haul trucks to strategically placed ore transfer raises that were dedicated to a particular ore type (Figure 27). Located in the stable footwall of the ore body, the ore transfer raises were connected to underground ore bins above the Hopewell tunnel on the 1,000-foot haulage level of the underground mine. Waste rock was delivered to underground storage bins via waste transfer raises and used to backfill mined-out stopes throughout the underground operation. Excess waste from the open pit was transported to nearby surface waste dumps (Alenius, 1930).



Figure 28. Loading burning ore with 1.75-cubic yd. Bucyrus-Erie 50-B electric shovel on 5240-foot level of the United Verde open pit. Circa 1926 (Alenius, 1968).

Between 1924 and 1927, mining operations in the "lower pit" encountered numerous challenges related to burning ores and timbers in the underground workings (Figure 28). The pit was commonly filled with smoke, at times limiting visibility to 300 feet. One of the most serious problems was blasting of hot ground within and around the burning sulfides. Locally attaining temperatures up to 780 degrees F., blast holes had to be cooled to less than 120 degrees F. before blasting could safely proceed. Water, sand or a combination of the two were used to reduce the temperature in the blast holes. In some instances blasting operations employed specially designed insulated cartridges, known as torpedoes that were filled with explosives. It was not uncommon during night operations for heat emanating from burning ores to cause shovel dippers and haul truck bodies to glow a dull cherry red. Not only did burning ore impact surface operations, it also presented special problems for the underground ore handling infrastructure. Damage to underground infrastructure was minimized by mixing small amounts of burning ore within non-burning material (Alenius, 1968).

Another challenge encountered in the early open pit operations at United Verde included the presence of underground mine workings. Both filled and unfilled square-set stopes were encountered. Old timbers had to be separated from the ores to avoid blockages in the ore transfer raises and ore chutes. Efforts were also made to avoid dumping large rocks into ore transfer raises to avoid blockages (Alenius, 1930).



Figure 29. One of six large tunnel (aka "coyote") blasts that were used to expedite stripping operation at the United Verde open pit. Circa mid 1920s (Alenius, 1968).

By the fall of 1924, hard unaltered gabbro in the hanging wall of the United Verde ore body that was exposed in the upper benches of the open pit caused stripping operations to fall behind levels required to keep up with ore production in the "lower pit". Over the next two years, this problem was resolved

by a series of six large "coyote" (tunnel) blasts on the 160-foot level that exposed more of the ore body (Figure 29). By the time the initial phase of stripping was completed in October 1927, these blasts had produced an unbroken high wall above the 160-foot level that in places exceeded 500 feet, creating hazardous working conditions for both workers and equipment (Alenius, 1968).

Much of the backfill contained in the many of the old underground stopes encountered by United Verde's open pit operation was shipped directly to the Clarkdale smelter (Alenius, 1930). This was due to several factors:

- Low grade material used to backfill stopes during early underground operations was deemed commercial.
- Early underground operations were not very efficient, commonly leaving enough high-grade ore dispersed throughout the low-grade backfill to make it profitable to mine.
- Enrichment of backfilled stopes through the precipitation of copper-bearing minerals from descending groundwater and ascending gases from the mine fires.
- Some zones were enriched through the removal of sulfur by in-situ roasting of the sulfides during the mine fires.

Clarkdale Smelting and Metallurgical Operations. Early expansions to the Clarkdale smelting facility included the addition of six roasters in 1917 and three 25-foot by 101-foot reverberatory furnaces during 1919. A second 430-foot brick stack was added to the facility in July 1922 with the addition of Cottrell dust precipitation plant, which was designed to reduce metals losses from the roaster, converter and blast furnace gases (Lanning, 1930). By this time, the Hopewell crushing plant was unable to meet production demands. It was replaced by a new crushing plant that was commissioned at the Clarkdale smelter in November 1923 (Keefe, 1930). The electricity generating station was expanded in 1924 and again during 1927 to meet increasing demands for power at the smelter and mine.

In 1924, metallurgists at United Verde began studying ways to solve two problems: 1) reducing sulfur emissions at the smelter by developing an economical process to recover iron and sulfur from pyrite-rich ores, and 2) reducing the overall cost of smelting. Experiments were performed at Southwest Metals' mill at Humboldt, Arizona. Although they never developed an economical process to recover iron and sulfur from their pyrite-rich ores, this research demonstrated that if the more refractory black schist ore (25 to 30% of the smelter feed) was mined separately and concentrated prior to smelting, overall smelting costs could be reduced by 15 to 25 cents per ton. Design work on the concentrator began in August 1925 and the 1,000 ton per day facility was commissioned in March 1927 (Barker, 1930). Use of the blast furnaces was discontinued in November 1929, with all ore and concentrates being treated by roasting, reverberatory smelting and converting.

Serious attention was given to using flotation to recover zinc from the massive pyritic ores from United Verde prior to 1930, but the process was deemed impractical due to perceived metallurgical problems.

Research solved many of these challenges, justifying the construction of an independent 500-ton per day flotation circuit designed to produce copper and zinc concentrates (Ralston, 1930). However, this project was not completed before operations were suspended at the concentrator in July 1930.

Underground Mine Fires Extinguished. During 1927, an attempt was made to fight the underground mine fires with tailings from the recently commissioned Clarksdale concentrator. This involved pumping tailings into churn drill holes in the fire areas, sealing the cracks and crevices that supplied oxygen to the underground fires. The technique worked so well that a sliming mill was erected adjacent to the open pit, which eliminated the high costs of transporting tailings from the Clarksdale concentrator. This 65-ton/shift facility employed a jaw crusher, rolls, and ball mill to produce a 35% minus 100 mesh slurry at 50% moisture from waste rock, which was used by both open pit and underground operations (Alenius, 1930).

Boom Years at United Verde. From the resumption of operations in June 1922, annual ore production at United Verde rose steadily from 1.1 million tons in 1923 to 1.8 million tons in 1929. Copper production peaked at 142.3 million pounds in 1929 (DeWitt and Waegli, 1989). Similarly, the communities of Jerome and Clarksdale also prospered with the influx of new residents. Prospects for the future seemed bright, but events soon lowered expectations.

Unstable Ground Slows, then Halts Open Pit Operations. By June 1929, open pit mining operations had progressed to below the 300-foot level. At 4:00 AM on the morning of June 30, 1929, workers in the pit heard very sharp noises resembling explosions as a large area in center of the pit adjacent to the western wall suddenly dropped approximately 4 to 5 feet. Workers moved equipment from the affected area and evacuated the pit (Alenius, 1968).

Upon inspection over the next several days, the total extent of the collapse was ascertained. The gabbro in the hanging wall of the ore body had broken away over a width of more than 300 feet, which extended upward beyond the crest of the pit wall that was more than 650 feet above the lowest pit level. The collapsed section had dropped more or less as a single block with only about 25,000 tons of loose rock falling into the open pit (Alenius, 1968). It was subsequently determined that the collapse was triggered by a large cave-in that dropped underground levels above the 1,200-foot level by about 5 feet, necessitating redevelopment of all of these levels before underground mining activities could safely resume in the affected area (Pullen, 1941).

After monitoring the situation for several days, it became evident additional large slides were not imminent. Mining was permitted in the far side of the pit, while workers cleared away loose rock from above the collapsed area, permitting full operations to resume. Approximately twenty survey stations were established in and around the collapsed area and were periodically monitored for ground movement. These studies predicted the major slope failure that occurred in March 1931, when more than 1,000,000 tons of debris from on northwest wall slid into the pit, halting ore production at United Verde's surface operation (Figure 30). Fortunately, advance warning of this event allowed all personnel and equipment to be safely evacuated from the pit prior to the slope failure (Alenius, 1968).



Figure 30. The pit wall failure of March 1931 involved more than 1,000,000 tons of rock, which measured about 600 feet wide, covering the lowest working bench (5175-foot level). Some of the fragments were as large as a house (Alenius, 1968).

United Verde Operations Negatively Impacted by Great Depression. On Tuesday, October 29, 1929, the U. S. stock market experienced a sudden devastating collapse at the onset of the Great Depression. Although impact of this event was not immediately felt by many of Arizona's copper producers, the gradual decline in the price of copper (from 17.8 cents per pound in October 1929 to a low of 4.8 cents per pound in early 1933) made it increasingly difficult to maintain profitable operations. Treatment of lower grade ores by United Verde Copper's concentrator was suspended in July 1930, resulting in 825 workers being laid off. As the price of copper fell below 9 cents per pound in May 1931, United Verde's management decided to suspend all underground ore production and smelting operations. At the time copper production was suspended in May 1931, underground mining operations had reached the 3,150-foot level.

During the shutdown, a reduced workforce was retained for care and maintenance of the company's assets and to continue limited underground development. Collared at the surface on the 300-foot level in January 1930, the No. 7 shaft was completed to the 3,000-foot level during 1933. A surface crew was also retained to remove the debris from the March 1931 slide and resume badly needed stripping of more than 6 million cubic yards of waste from the highly fractured hanging wall of the ore body (Alenius, 1968).

Rail access was re-established on the old, previous constructed switchbacks and waste dumps and the old steam locomotives and dump cars were placed back into service. Two 4-cubic yard, electric Bucyrus-Erie 120-B shovels were retained to progressively cut 50-foot benches down to the 5,525-foot elevation level. Below the 5525-foot level, mining was confined to the removal of the fractured hanging wall and debris from the March 1931 pit wall failure. Some of the caved material consisted of large fragments, which were as large as a house that needed to be dislodged and reduced to smaller sizes prior to

removal. All of this was done beneath a 200-foot high wall under extremely hazardous conditions, requiring constant scaling and trimming of loose debris.

During 1934, a cut was made into the open pit from the 300-foot level, allowing rail access into the pit to facilitate waste removal below the 160-foot level. This provided a direct rail link from the mine to the Clarkdale smelter, eliminating the surface operation's need for ore transfer raises to the underground ore handling infrastructure. Copper production resumed from the 5,175-foot level of open pit in January 1935 (Alenius, 1968).

Table 5. United Verde production from 1888 through February 18, 1935 (DeWitt and Waegli, 1989). Total dividends paid for the period, 1892-1933.

Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.	Dividends US \$
20,699,096	1,981,868,413	0	0	915,873	33,083,345	102,210,000

An End of an Era. On February 18, 1935, the Phelps Dodge Corporation acquired the United Verde operation through its purchase of the United Verde Copper Company (Anonymous, 1981). Over the 47-year period that William Clark and his heirs controlled the United Verde Copper Company approximately 20.7 million tons of ore were mined, recovering nearly two billion pounds of copper, more than 900,000 ounces of gold and more than 33 million ounces of silver. Throughout this period, the United Verde Copper Company paid more than \$102 million in dividends to its shareholders, with Clark and his heirs receiving more than 95% of the proceeds (Table 5).

### **United Verde Extension (1900 - 1938)**

Prior to 1900, the United Verde operation was the Verde Mining District's lone producer. Attempts to search for extensions of the United Verde ore body in the surrounding area were thwarted by the northwest striking Verde Fault, which down-dropped the favorable host rocks in its northeast hanging wall, concealing them beneath a thick section of barren strata that impeded its evaluation (Figure 3). This situation was further hindered by William Clark, who did not permit visitors to examine the underground workings of the United Verde mine (Rickard, 1918).

George W. Hull, a resident of Jerome since 1883, recognized the importance of acquiring the mineral rights of the ground surrounding United Verde Copper's holdings, if extensions of the United Verde ore body could be traced onto adjacent ground. Over the next decade he acquired claims to the west, south and east of United Verde Copper property, surrounding it on three sides. Hull organized the United Verde Extension Mining Company under Arizona law in 1894 (Stevens, 1902).

In March 1899, Louis Whicher of Boston, Massachusetts became interested in the Verde Mining District and entered an agreement with George Hull that resulted in the formation of the United Verde Extension Gold, Silver and Copper Mining Company, which controlled ground west and south of the United Verde deposit. Whicher purchased 190,000 shares for \$100,000, becoming its majority

shareholder. Hull retained control of the remaining 110,000 shares. A shallow shaft was sunk on the "1888" claim, which is located immediately west of United Verde's smelter, but failed to encounter ore (Rickard, 1918).

Search for a Concealed Ore Body. During 1900, John J. Fisher, a Deputy Mineral Surveyor, discovered an unclaimed fraction covering less than an acre between the March claim belonging to Hull and the Daisy claim held by the United Verde Copper Company. He located the fraction under the name "Little Daisy". Based on advice from a competent engineer, who believed potential for future discoveries was better east of United Verde's property, Whicher acquired a purchase option on the Little Daisy property for \$50,000. These funds were used to sink a 300-foot shaft, which encountered weakly mineralized host rocks, similar to those found at United Verde (Rickard, 1918). The Little Daisy claim was patented on July 8, 1901 (Government Land Office Document - 34110).

Encouraged by the results of this exploration effort, Louis Whicher negotiated a deal with George Hull during the fall of 1900 that permitted him to acquire March, Conglomerate, Iron Carbonate and Bitter Creek claims and Hull's 110,000 shares of the United Verde Extension Gold, Silver and Copper Mining Company in exchange for his interest in the other properties owned by the company (Tenney, 1927). George Hull would later organize the Consolidated King and Columbia Copper Mining Company, Cleopatra Copper Company (1902), and Hull Copper Company (1906) to explore and develop his other holdings, which were sold to Charles W. Clark, the son of William Clark, in 1916 for \$1 million (Brogdon, 1952).

Shortly after this acquisition, Whicher exercised his option to purchase the Little Daisy claim from Fisher for 5,000 shares of United Verde Extension Gold, Silver, and Copper Company stock. This company was reorganized in 1902 as the United Verde Extension Mining Company under the laws of Maine with the same capitalization (300,000 shares valued at \$10 per share). A second reorganization of the company was undertaken in 1910 under the laws of Delaware with the capital increased to 400,000 shares of the same par value (Rickard, 1918).

The Little Daisy Shaft was sunk to a depth of 800 feet and exploration drifts were driven under the direction of John Fisher. By the summer of 1911, \$500,000 had been spent with exploration efforts only encountering small ore pockets. Although this was tantalizing, it was not the success United Verde Extension's investors had envisioned. Exploration activities were discontinued.

Having received both positive and negative appraisals on the property's potential, Major A. J. Pickrell, one of the directors of the United Verde Extension Mining Company, invited James S. Douglas Jr. to visit the UVX property (Figure 31). Douglas was familiar with area, having worked at the Senator, Big Bug and Bumblebee mines in Yavapai County. Known as "Rawhide Jimmy" by workers at Phelps Dodge's Nacozari mine in Sonora, Mexico, his father was Dr. James Douglas, the President of Phelps Dodge and Company, Inc. James S. Douglas visited the UVX property in December 1911 and examined the workings on the 800-foot level. Favorably impressed with the property's potential, Douglas acquired a purchase option on the UVX property and offered it to Phelps, Dodge and Company. However, they chose to not pursue the matter due to a perceived defect in its title.



Figure 31. James "Rawhide" Douglas (photo provided by University of Arizona Special Collections).

At this point, Major Pickrell urged the younger Douglas to financially back the project (Rickard, 1918). In April 1912, Ira Joralemon, a mine geologist at the Calumet and Arizona Mining Company, examined the property. Based on this examination, Joralemon predicted good sulfide ore would be found at a moderate depth below the leached and mineralized material on the 800-foot level. In summary, he stated, "While the result of the work is a gamble, there is a chance of finding a mine worthy of being compared with the United Verde. I think the chance is worth taking" (Rickard, 1918).

With this information, Douglas was able to persuade George E. Tener, one of the organizers and directors of the Calumet and Arizona Copper Company, to join the venture. The United Verde Extension Mining Company was reorganized in August 1912. It was capitalized at \$750,000 with 1.5 million shares at \$0.50 per share. The original shareholders retained 380,000 shares. James S. Douglas and George E. Tener received 170,000 shares for their management of the project. This included compensation paid to others, who had assisted in the reorganization of the company. Working capital (\$225,000) for the project was raised through the sale of 50,000 shares to Douglas and Tener and 400,000 shares offered to friends and professional acquaintances, the most notable of which included Dr. James Douglas, Walter Douglas, John C. Greenway and Louis D. Ricketts (Rickard, 1918).

With financing in place, a drift on the 800-foot level was extended eastward to explore their holdings. A decision was made to sink a second more centrally located shaft from which exploration could be conducted. The Edith shaft was collared approximately 1,700 feet east of the Little Daisy shaft in June 1913. Exploration drifts were developed on the 800-foot, 1,200-foot and 1,400-foot levels (note: levels

of the United Verde Extension (UVX) Mine are related to the distances below the collar of the Little Daisy shaft). These efforts failed to find ore (O'Brien, 1991). Drifts exploring the Main Top claim, which had been optioned from the Jerome Verde Company, also proved unsuccessful. By this time \$225,000 of working capital had been spent. UVX's shareholders were asked to subscribe for their proportion of additional treasury stock (50,000 shares) at \$1 per share. This they did without a second thought.

With financing once again in place, exploration continued on the 1,200-foot and 1,400-foot levels. By September 1914, the treasury was once again nearing depletion without any commercial ore being found. Unwilling to ask investors to purchase more treasury stock, Douglas and Tener each advanced \$25,000 to continue the search. To satisfy themselves and other investors, they retained the services of the prominent geologist to review their exploration program. After a thorough examination, he recommended they abandon their effort. Still having faith in the project, Douglas and Tenner decided to follow an old Cornish miner's proverb; "never abandon a drift until you have driven 20 feet farther". A short time later, a cross-cut driven toward the center of the property on the 1,200-foot level encountered 5 feet of chalcocite-bearing ore, averaging 45% copper on December 20, 1914 (Rickard, 1918). After fourteen long years of exploration, the United Verde Extension Mining Company found its first commercial ore body. But little did they know that a much larger ore body awaited discovery. United Verde Extension relinquished its option on Jerome Verde's Main Top claim in June 1915 after finding no commercial ores.

The December 1914 discovery measured 120 feet long and reached a few feet above the 1,100-foot level. The first shipment of ore (76 tons) was made to United Verde Copper's Jerome smelter in February 1915, yielding returns of \$75,000 (Rickard, 1932). However, much of this early production was transported by burro to the newly completed rail head at Hopewell (entrance of Hopewell tunnel) (Weed, 1916).

Efforts to delineate the downward extension of the December 1914 discovery were made from a drift that was driven on the 1,400-foot level, but these efforts failed to intersect the ore body. No further exploration was conducted until January 1916, due to a heavy flow of groundwater that had been encountered south of the ore body on the 1,200-foot level. After dewatering the lower workings was completed, a cross-cut was driven east and west on the 1,400-foot level to search for the ore body. It also failed to find the continuation of the ore body encountered on the 1,200-foot level. A second cross-cut was driven 100 feet farther south and found nothing. In February 1916, a third cross-cut encountered more than 200 feet of ore, averaging 16% copper. Once the news of the great UVX discovery became known, the price of UVX stock jumped from 50 cents to \$45 per share (Rickard, 1932).

UVX, a Brilliant Deduction or Serendipitous Discovery. The United Verde Extension was one of Arizona's first major copper deposits in which an understanding of geology played an important role in its discovery. Unlike all prior discoveries that had been exposed at the surface, the UVX was completely concealed beneath barren cover. Based on their knowledge of the geological setting of the Verde Mining District, they assumed an upper portion of the United Verde ore body may have been offset by the Verde Fault and now lay concealed beneath Phanerozoic strata in its northeastern hanging wall. This interpretation provided the incentive to explore the virgin ground in the hanging wall of the Verde

Fault zone. When the UVX ore body was discovered in early 1916, James S. Douglas was convinced it was the faulted off apex of the United Verde deposit, despite his mining engineers observations that showed it only touched the main plane of the Verde Fault and was not cut by it (Lindberg, 2018).

Only after detailed mapping of the district during decades following the closure of the UVX mine have geologists come to realize the United Verde and UVX deposits are in reality two separate distinct deposits that lie on opposite-facing limbs of the Jerome Anticline; each containing its own magnesium rich chlorite footwall alteration (i.e. black schist) at the top of the lower member of the Cleopatra Rhyolite (Lindberg and Jacobson, 1974). In retrospect, the UVX was more of a serendipitous discovery that involved an incorrect interpretation of the geological data.



Figure 32. Surface facilities at United Verde Extension mine with James Douglas' residence in the background - circa 1918 (Anonymous, 1918b).

Mine Development and Erection of the Clemenceau Smelter. Over the next two years, the new discovery was readied for commercial production (Figure 32). Underground activities included the delineation and development of the ore body on several levels. By 1917, development had delineated an ore body measuring 260 feet wide by 440 feet long, containing a core of massive chalcocite and pyrite assaying more than 40% copper (Tenney, 1927). Much of this work, as well as development of surface infrastructure, was financed from the production of rich development ores, which averaged 22.7% and 27.5% copper in 1916 and 1917, respectively (Weed, 1922). Annual copper production peaked at 63.9 million pounds during 1917, enabling the United Verde Extension Mining Company to post \$8.3 million of net earnings. That is equivalent to \$148 million in 2017 dollars!

A 4,600-foot aerial tramway was constructed in early 1916 (?), connecting surface bins adjacent to the Edith shaft with ore storage bins located along the Verde Tunnel and Smelter Railway between Hopewell and Clarkdale. Composed of sooty chalcocite ( $\text{Cu}_2\text{S}$ ), these ores resembled cannel coal that blackened ones fingers. Some carloads assayed 40% copper. Prior to the commissioning of its own smelter, UVX ores were shipped via rail for custom smelting at facilities in Humboldt, Douglas and Globe.

Originally designed as an exploration shaft, it was clear the Edith shaft would not meet the needs of the growing operation. A new, concrete-lined production shaft, known as the Audrey shaft was sunk approximately 200 feet east of the Edith shaft during 1917. In 1918, the United Verde Extension Company completed the Little Daisy Hotel, which served as a boardinghouse for its workers (Figure 33). It had 40 rooms, a billard and pool room, and spacious dining area (O'Brien, 1991).



Figure 33. Constructed in 1918 by the United Verde Extension Company, the Little Daisy Hotel served as a boardinghouse for its workers until 1938. It has been recently remodeled into a private residence. Circa 2012 (photo provided by Jan Rasmussen).

Excavation of the 12,384-foot Josephine ore haulage/drainage tunnel (elevation - 3,755 feet) began in July 1917. Completed in April 1919, this tunnel connected the 1,300-foot level of UVX mine with an adit located 3.75 miles from the UVX smelter near Cottonwood, Arizona (O'Rourke, 1918). Ore haulage operations began in November 1919, eliminating the need for the aerial tramway.

The United Verde Extension Mining Company organized the Arizona Extension Railroad on September 15, 1916 to transport ore from the mouth of the Josephine tunnel to the UVX smelter (Farley, 2016). Initial construction of a 3.5-mile standard gauge rail line connecting the Verde Valley Railroad in Clarkdale with the UVX smelter site near Cottonwood, Arizona was completed on July 26, 1917. This

helped expedite the on-going construction of the smelter. A 3.75-mile branch line connecting the smelter with the portal of the Josephine tunnel was completed in March 1918 (Irvin, 1987).



Figure 34. First copper anode from the UVX smelter in Verde (renamed Clemenceau in 1920) was cast on July 18, 1918. It is on display at the Jerome State Historic Park (photo provided by Jan Rasmussen).

James S. Douglas made the decision to build a smelter to process ores from UVX's new discovery on April 23, 1916. The location chosen for this new facility was on land owned by the C. V. Hopkins ranch, situated approximately 1 mile south of Cottonwood, Arizona (Farley, 2016). This site was initially named Verde (Brogdon, 1952). The United Verde Extension Mining Company hired A. J. McGregor of Warren, Arizona to design their 1,000-ton per day smelting facility. Grading of the site began on April 13, 1917 and construction commenced on July 1, 1917. The UVX smelter was commissioned at a total capital cost of \$5.1 million and cast its first copper anode on July 18, 1918 (Figure 34). Smelter workers resided in a company town located adjacent to the smelter, which was renamed Clemenceau in 1920 to honor George Clemenceau, prime minister of France, who was a close personal friend of James S. Douglas (Brogdon, 1952).

UVX Mining and Smelting Operations. Following the end of World War I in November 1918, the price of copper fell from 26 cents to 12.4 cents per pound, which resulted in the suspension of smelting operations at the Clemenceau smelter on May 1, 1921 (Tenney, 1927). The UVX mine resumed production on March 1, 1922.

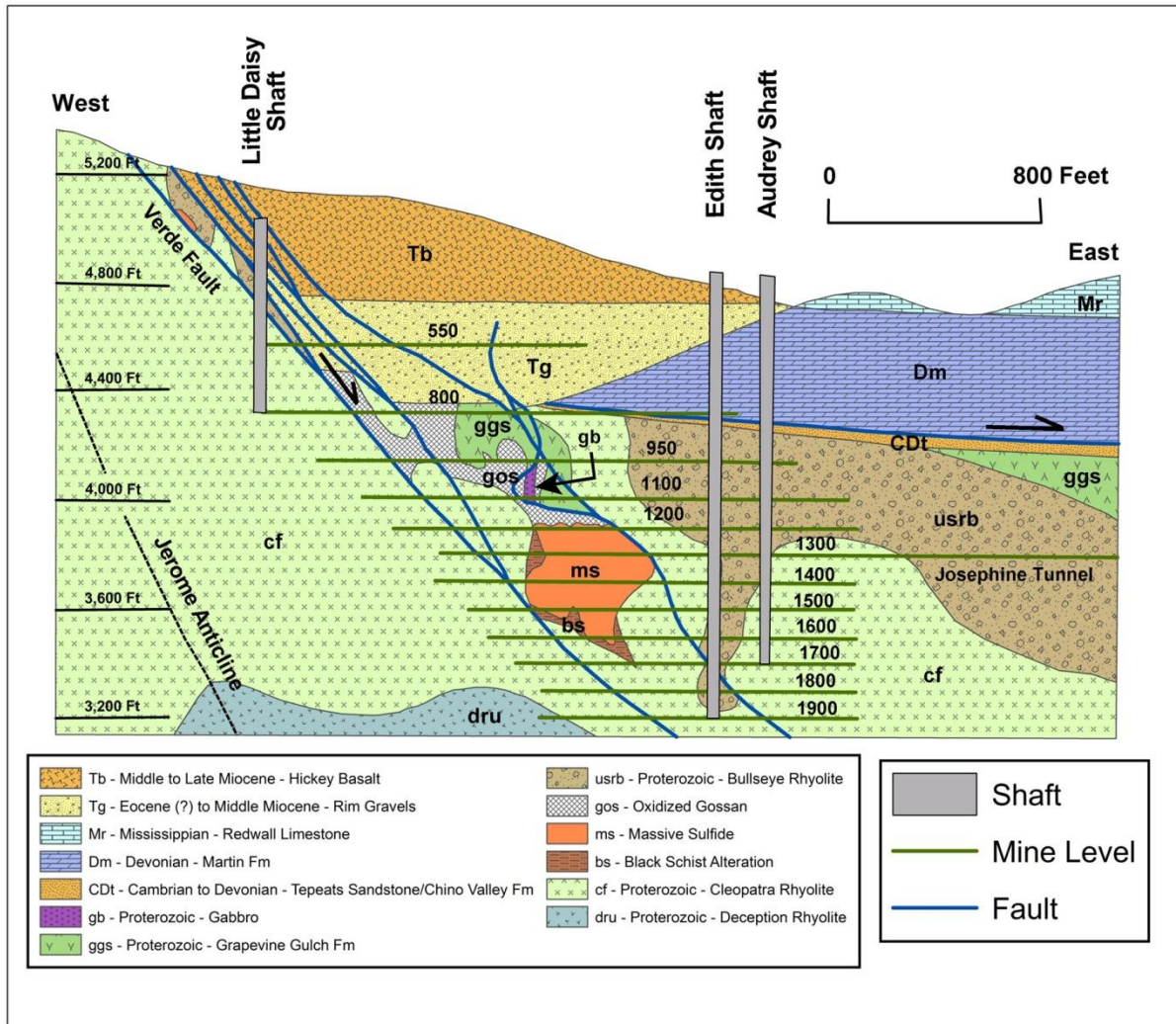


Figure 35. Schematic east-west cross section of the United Verde Extension Mine showing general geology, shafts and mine levels. Note: The shafts are located behind the plane of the cross-section (modified from Lindberg, 1992).

The United Verde Extension Mine was developed on twelve levels; the 550-, 800-, 950- and 1,100-foot levels and on 100-foot intervals from the 1,100- to 1,900-foot levels (Figure 35). The main ore body was developed on the 1,300-, 1,400-, 1,500- and 1,600-foot levels, while smaller distal zones were mined on all levels from 550- to 1,700-foot levels (D'Arcy, 1930).

The UVX operation mined three types of ore; massive sulfide ore, siliceous sulfide ore and siliceous gold ore. Rich massive sulfide ores from the main ore body and several smaller "drag" ore bodies located along the Verde Fault were mainly composed of chalcocite and cuprite with modest gold values of 0.040 oz./ton. The siliceous sulfide ores were derived from the Maintop (1110, 1202, and 1210) stope, the 1307-A stope and the 1205 stope. In addition to containing significant amounts of copper, these stopes generally assayed more than 0.1 oz. Au/ton and 1.0 oz. Ag/ton. The copper content of the siliceous gold ores from the "gold stope" was nil, but averaged 0.4 oz. Au/ton and 2.0 oz./Ag/ton. The ability to ship

both massive sulfide ore and gold-bearing silica flux to their Clemenceau smelter helped make UVX a very profitable operation (White, 1986).

Due to the heavy nature and richness of the massive sulfide ores, an overhand square-set mining method was employed to extract the ore from the stopes, which were tightly filled with waste once the ore had been extracted. A modified Mitchell slice method was employed for pillar recovery. These methods made it possible to recover the entire ore body with practically no dilution. Furthermore, it also allowed for the careful examination of the walls of the stope, which resulted in finding many small, rich lenses of ore that would otherwise have been missed (D'Arcy, 1930).

Main haulage levels in the main ore body were located on the 1,400-foot and 1,600-foot levels. Production from higher levels was transferred to the main levels by a series of ore transfer raises. Haulage was performed by 5-ton trolley locomotives with 30-cubic foot side-dump ore cars. The ores were transported to loading pockets located adjacent to the Audrey production shaft (D'Arcy, 1930).

The Edith and Audrey shafts were 3-compartment, vertical shafts, located approximately 200 feet apart and approximately 1,000 feet north of the main ore body. The concrete-lined, Audrey shaft was used as the main production shaft, which hoisted two 3-ton ore skips running in counterbalance. The Edith shaft was originally sunk as a timbered, exploration shaft. Upon completion of the Audrey shaft, the Edith shaft was converted to a service shaft and was used for transporting mine personnel and supplies in and out of the mine. It was concrete-lined from the 1,400-foot level to the surface during 1921 (D'Arcy, 1930). Ventilation was provided by a 40,000-cubic foot per minute exhaust fan installed at the top of the older Little Daisy shaft and a 135,000-cubic foot per minute fan placed at the top of an air-raise (Weed, 1922). A second raise was used to convey surface waste for backfilling mined out stopes (Mitke, 1920).

Like the United Verde, the high sulfide content of the ores and use of heavily timbered stopes also posed a fire hazard at the United Verde Extension operation. Although rock temperatures were not very high, oxidation of sulfides and timber decay released considerable amounts of heat, requiring a well-designed ventilation system to prevent conditions favorable for spontaneous combustion. Lessons learned from the older United Verde operation were successfully applied at UVX.

The ore was hoisted to the 1,100-foot level, where it was dumped into ore chutes that led to the main ore pockets located between the 1,200- and 1,300-foot levels. There were two 1,000-ton capacity ore pockets for direct smelting sulfide ores and a single 350-ton capacity ore pocket for silica converter ore. From the ore pockets the ores were loaded into trains in the Josephine haulage tunnel on the 1,300-foot level. Rail haulage through the tunnel was performed by 25-ton standard gauge electric-powered locomotives with eight 30-ton ore cars. At the portal, these trains were reconfigured into 16-car trains, which were transported to the smelter by a steam locomotive (D'Arcy, 1930).

The Clemenceau smelter included a single 48-inch by 26.7-foot blast furnace, two 25-foot by 120-foot reverberatory furnaces, six 21.5-foot six hearth Wedge roasters, and three 12-foot Great Falls converters. Its reverberatory furnaces were fueled by pulverized coal, which was the first time this was

attempted in Arizona (Weed, 1922). Its 425-foot smoke stack was reported to be the tallest stack in world at that time (Rickard, 1987).

Impacts of Smelting Copper Ores on Verde Valley Residents. Development of the mines at Jerome was initially welcomed by farmers in the Verde Valley. With the closure of military posts such as Fort Verde, the mining camp assured a nearby market where their produce could be sold for 25% to 50% more than could be obtained from less accessible distant markets in Prescott and Flagstaff. United Verde Copper's Jerome smelter and early roasting operations posed few problems for the Verde Valley farming communities because their location high on the northeast slope of the Black Hills allowed their gaseous emissions to be dissipated over a large area (McCarthy, 2014).

However, everything changed in May 1915 with the relocation of United Verde's smelter to Clarkdale. Even with its 400-foot stack, pollutants were no longer adequately dispersed as they had been at the Jerome smelter. The commissioning of the United Verde Extension's smelter near Cottonwood, Arizona in July 1918 only compounded this problem. Situated between the Black Hills and Mogollon Rim, the Verde Valley commonly experienced thermal inversions that trapped smelter smoke along the valley floor until weather patterns changed. These events had dramatic impacts on fields and orchards in the Verde Valley, sometimes destroying a season's harvest overnight. Many residents experienced respiratory ailments as a result of breathing the polluted air (McCarthy, 2014).

In an effort to resolve their differences with the mining companies, Verde Valley's farmers organized the Verde Valley Protective Association (VVPA) in 1916. However, the United Verde Copper Company and United Verde Extension Mining Company convinced many members of this organization to sell their damaged farms to the companies, who then attached smoke easements to the land and resold the farms at a much reduced price. Thirteen members of the VVPA refused to sell their properties and filed the first of many lawsuits against the mining companies in 1918. After an extended legal battle, their case was heard by the United States Supreme Court in 1925, which decided in their favor, but only granted one-third of their requested settlement (McCarthy, 2014).

Table 6. Cost data for the United Verde Extension Mine from 1921 through 1931. Data expressed in cents per pound of copper recovered. These costs do not include depreciation, depletion or taxes. Other cost data for 1929 and 1930 include 1.19 and 1.46 cents per pound for custom ore purchased. Source: Cost data for the United Verde Extension operation was obtained from the Mineral Resources of the United States Minerals Yearbooks published by the U.S. Geological Survey (1921-1923) and U. S. Bureau of Mines (1924-1931).

Year	Mining Costs	Smelting Costs	Freight on Ore Costs	Shipping, Refining and Selling Costs	Other Costs	Total Costs	Average Copper Price
1921	5.90	3.17	0.22	3.55	0.62	13.46	12.50
1922	2.32	2.26	0.07	2.11	0.17	6.93	13.38
1923	2.72	2.31	0.08	2.08	0.08	7.27	14.42
1924	2.84	2.61	0.08	1.87	0.09	7.49	13.02
1925	2.46	2.32	0.08	1.80	0.27	6.93	14.04
1926	2.51	2.10	0.09	1.76	0.01	6.47	13.80

Year	Mining Costs	Smelting Costs	Freight on Ore Costs	Shipping, Refining and Selling Costs	Other Costs	Total Costs	Average Copper Price
1927	2.67	2.50	0.10	1.81	0.14	7.22	12.92
1928	2.67	2.70	0.09	1.82	0.22	7.50	14.57
1929	2.47	2.33	0.08	1.72	1.86	8.46	18.11
1930	2.84	2.32	0.08	1.79	1.46	8.49	12.98
1931	2.69	2.31	0.07	1.77	0.30	7.14	8.12

Boom Years at the United Verde Extension Operation. After smelting operations resumed at United Verde Extension in March 1922, ore production steadily increased from 172,629 tons in 1923 to 360,804 tons in 1929, while the tenor of the ores declined from approximately 12.1% to 8.7% copper, respectively. Annual copper production during this period rose from 30.6 million pounds in 1922 to 59.1 million pounds in 1929, while total operating costs ranged from 6.47 cents to 8.49 cents per pound of copper (Table 6).

An Aging Operation Exhausts its Remaining Reserves. The impact of the collapse of the U.S. stock market on Tuesday, October 29, 1929, was not felt by many of Arizona's copper producers. However, it was followed by a gradual decline in the price of copper from 17.8 cents in October 1929 to a low of 4.8 cents per pound in early 1933, making it increasingly difficult to maintain profitable operations. During this period, a small 200-ton per day flotation plant was added to United Verde Extension's Clemenceau plant in August 1930. This cost-savings measure helped to extend the life of the operation, which permitted the economic recovery of copper from leaner ores (1.5 to 4.5% copper) than the direct smelting process (6 to 8% copper) .

As the price of copper fell to 8.02 cents per pound in June 1931, United Verde Extension's management temporarily suspended all underground ore production and smelting operations on July1, 1931. Despite the continued decline in copper prices, operations resumed on November 1, 1931 because the United Verde Extension Mining Company could not afford to stop mining for a long period due a preexisting contract with the French government and deteriorating conditions of its mine (Clements, 2003).

Copper production from the UVX operation gradually declined from 35.8 million pounds in 1932 to 14 million pounds in 1936. The Clemenceau smelter was permanently closed on January 12, 1937, laying off 125 workers. Subsequent production from the United Verde Extension operation was shipped to Phelps Dodge's Clarkdale smelter. With the depletion of its remaining reserves, mining operations at UVX ceased on April 30, 1938. United Verde Extension Mining Company was dissolved in 1939 with its patented mining claims being acquired by the Clemenceau Mining Corporation. The physical assets of the Clemenceau Mining Corporation were purchased by Verde Exploration Ltd. in 1947.

Over its 23-year life, the United Verde Extension operation produced nearly 3.9 million tons of ore, averaging 10.23% copper. Nearly 789 million pounds of copper, 150,000 ounces of gold and 6.3 million ounces of silver were recovered over the life of the project (Table 7).

Table 7. United Verde Extension production from 1915 through 1938 (modified from Keith, 2017 and Anderson and Creasey, 1958).

Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.	Dividends US \$
3,880,667	788,533,189	0	0	149,764	6,332,167	50,531,250

The United Verde Extension Mining Company authorized the issuance of 1.5 million shares, of which 450,000 shares were never issued, leaving 1,050,000 shares of issued stock with a par value of 50 cents per share. Over the life of the project, stockholders received dividends every year (1916-1938), including the financially difficult years of the Great Depression. Dividends represented \$48.125/share of issued stock over the life of the project (Anderson and Creasey, 1958).

### **United Verde - Phelps Dodge Corporation (1935 - 1953)**

At the time of William Clark's death in March 1925, he held more than 95% of United Verde Copper Company stock (Anonymous, 1930). In 1929, his family purchased the 12,506 shares from by the estate of James MacDonald, who had been United Verde Copper's first president. William Clark's grandson, William Clark III died in a plane crash in 1932, and his sons, Charles Clark and William Clark, Jr. died in 1933 and 1934, respectively. William Clark's surviving heirs had little interest in mining and sold their equity in United Verde Copper Company (299,000 out of 300,000 shares) to the Phelps Dodge Corporation on February 18, 1935, for approximately \$20.8 million, including assumed liabilities. By August 1935, the remaining outstanding shares of the United Verde Copper Company had been acquired by Phelps Dodge, making it the wholly-owned United Verde Branch of the Phelps Dodge Corporation (Anonymous, 1981).

Open Pit Operations at United Verde. Concerned about slope stability in the unstable gabbro hanging wall of the open pit, management decided to postpone resumption of underground mining operations until surface operations neared completion. In spite of an second 400,000-ton slope failure in the southwest wall of the pit in March 1936, open pit operations proceeded at an accelerated pace over the next two and half years, during which more than 2.5-million tons of direct smelting and concentrating ores were shipped to the Clarkdale processing facility (Alenius, 1968).

During the first several of years after resuming open pit production in early 1935, rail haulage was employed on several levels of the open pit to remove both ore and waste that was mined by 4-cubic yard, Bucyrus-Erie 120-B electric shovels (Figure 36). This permitted the direct shipment of ore from the open pit to the Clarkdale smelter in 100-ton rail cars via the Verde Tunnel and Smelter Railroad, which eliminated the surface operation's dependence on ore transfer raises to the underground ore handling infrastructure. Pneumatic-tired, hydraulic-operated, side-dump, 20-ton haul trucks were placed into operation in 1935 for use in restricted areas where rail haulage was not practical. As the open pit became deeper and more restricted, rail haulage was gradually phased out in favor of the off-road haul trucks.

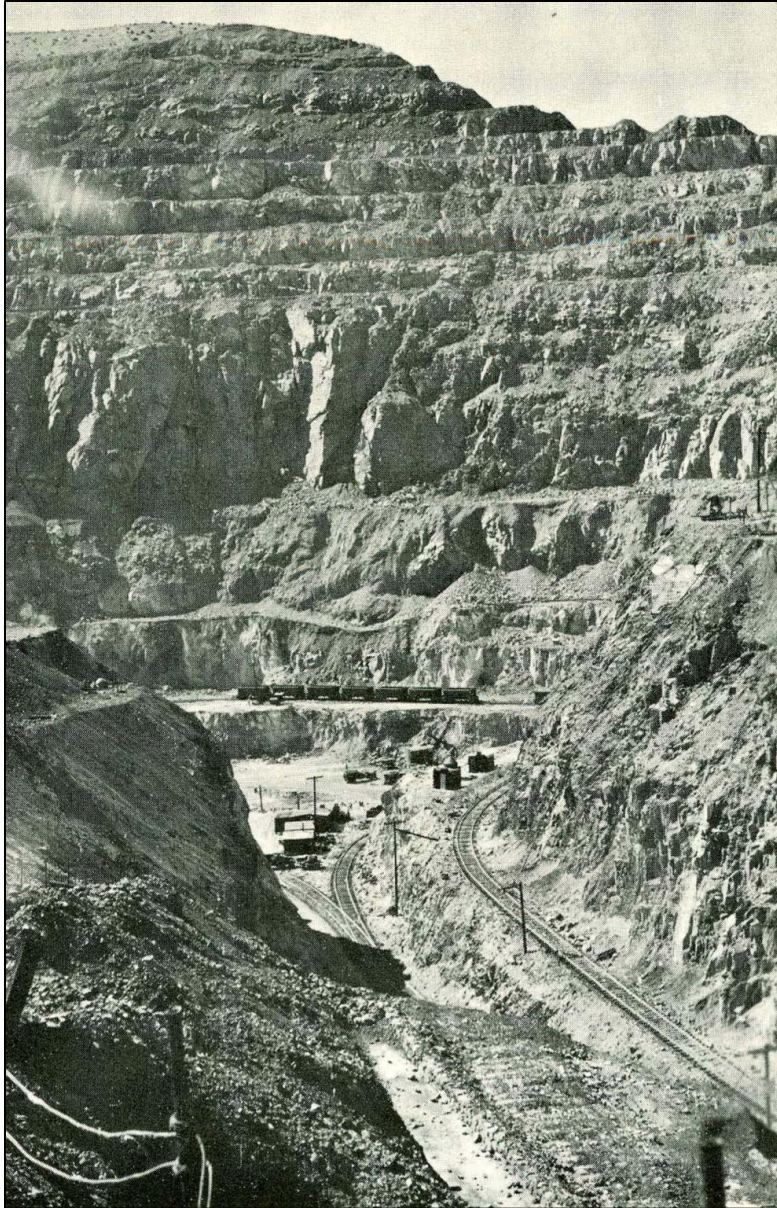


Figure 36. Open pit operations in October 1935. Fifty-foot benches in upper levels of the pit extend down to the 5,525-foot elevation bench. Below that, a 200-foot high bank rises above the 160-foot level bench, which is 150 feet above the ore cars on the 5,178-foot elevation bench. Elevation difference between the top of the cut and lowest working bench was approximately 820 feet (Alenius, 1968).

Production from the open pit declined rapidly in late 1937 as working benches in the lower levels of the pit became more restricted with depth and a greater percentage of the ore was derived from cleanup of the pit walls. Lower levels of the open pit were accessed by a steep, switch-backed haul road that was situated along the southeast pit wall, which provided access for the small electric shovels and 20-ton, side-dump haul trucks (Figure 37). When open pit mining operations were terminated in April 1940, the lowest level in the pit reached the 630-foot level (elevation 4,892 feet) of the underground operation, which was more than 1,100 feet below the highest point on the pit rim. More than 4,050,000-tons of

ore, which averaged 3.83% copper, 0.050 oz Au/ton and 1.45 oz. Ag/ton had been extracted from the open pit during the period, 1935 through 1940 (Alenius, 1968).



Figure 37. Twenty-ton, hydraulic-operated, side-dump haul truck that was placed in operation during 1935 (Alenius, 1968).

Underground Operations Resumed at United Verde. In an effort to supplement declining production from the open pit, small-scale, underground mining operations resumed in April 1937. At that time, the United Verde underground operation was developed on 100-foot levels from the surface to the 1,000-foot level with 200 feet separating the 1,000- and 1,200-foot levels, and on 150-foot levels from the 1,200-foot level to the 3,300-foot level (Figure 38). Access was provided by one shaft, two interior shafts (i.e. winzes) and two tunnels (Pullen, 1941).

Collared in 1915, the three-compartment No. 5 shaft extended from the 800-foot level to the 3,550-foot level (Pullen, 1941). Used to hoist ore from below the 1,000-foot haulage level, this shaft was concrete lined to the 3,150-foot level, below which it was timbered. It employed a double-drum hoist equipped with an 800-hp motor that was capable of handling 7.5-ton ore skips. The No. 5 shaft hoist room was on the 1,000-foot level and the ore pocket was at the 800-foot level (Anderson and Creasey, 1958).

Collared in 1919, the concrete-lined No. 6 service shaft extended from the 400-foot level to the 3,000-foot level and was used for handling men and supplies (Pullen, 1941). It was connected to the surface plant via a 1,600-foot adit on the 500-foot level. The No. 6 shaft was equipped with a single-drum hoist with a 500-hp motor that was capable of hoisting a counterweighted, double-deck cage, transporting 100 men or eight standard mine trucks. Its hoist room was located on the 500-foot level of the underground mine (Anderson and Creasey, 1958).

The five-compartment, concrete-lined No. 7 shaft extended from the surface (300-foot level) to 3,000-foot level. Collared in January 1929, it was sunk to replace the No. 5 and No. 6 shafts, if subsidence made these shafts unusable. However, neither the No. 5 shaft nor the No. 6 shaft was damaged

throughout the remaining life of the mine, making it unnecessary to use the No. 7 shaft (Anderson and Creasey, 1958). Data on the different shafts employed at the United Verde mine are shown in Table 8.

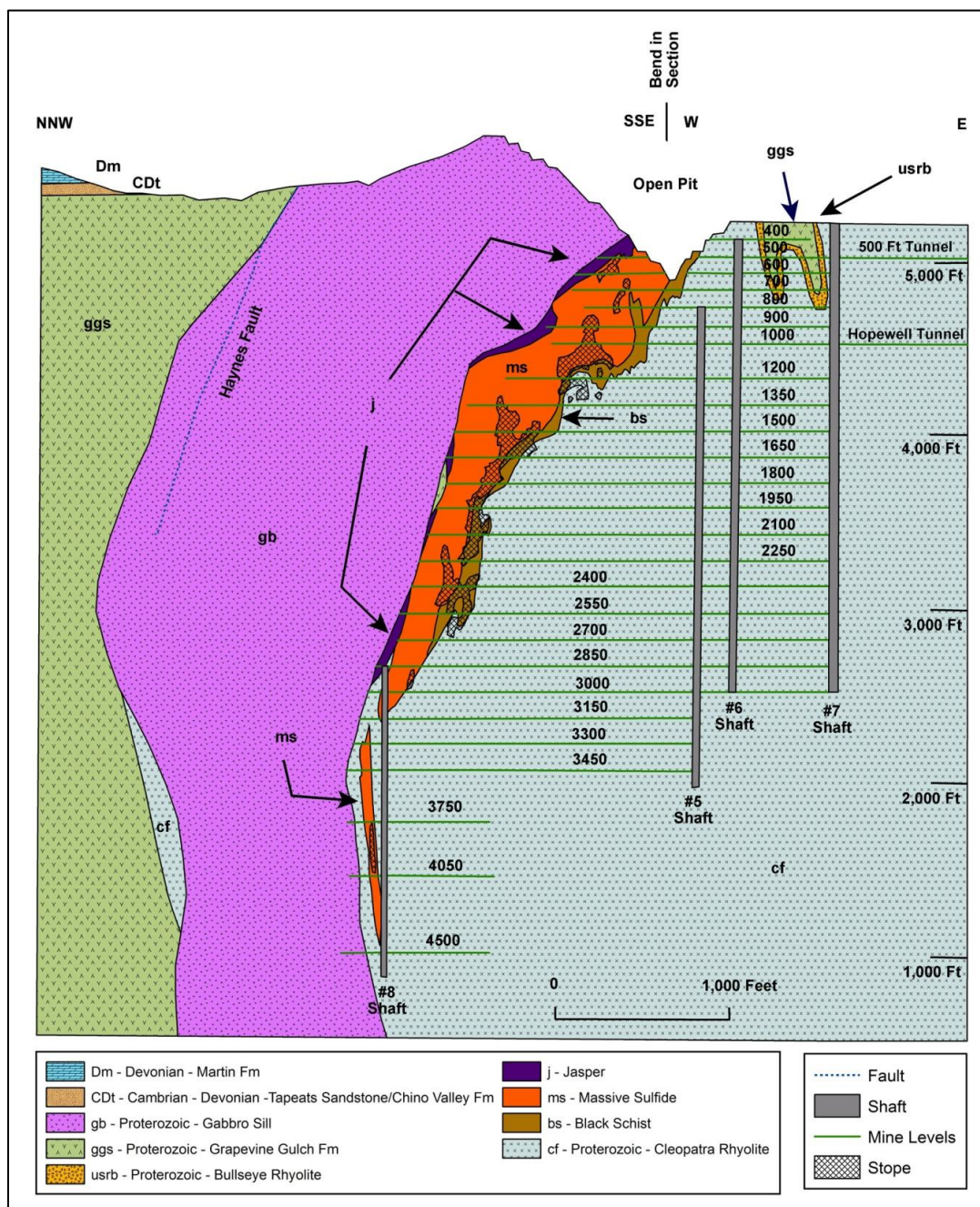


Figure 38. Schematic cross-section of the United Verde mine showing general geology, shafts, production stopes, and mine levels (modified from Anderson and Creasey, 1958). The No. 5 and No. 6 shafts are behind the plane of the section.

A system of ore passes above the 1,000-foot level were connected to the main ore pockets above the 1,000-foot haulage level. Twenty-five ton trolley-type locomotives with eight 40-ton, bottom-dump ore

cars transported the ore to the surface through the Hopewell tunnel. Backfill for the underground mine was dropped through transfer raises developed from the open pit to waste bins above the 1,000-foot haulage level and transported by standard gauge haulage equipment to a system of waste transfer raises that distributed it to lower levels of the mine (Pullen, 1941).

Table 8. Statistics for United Verde shafts.

Shaft	Start	End	Highest Level	Elevation (Feet)	Lowest Level	Elevation (Feet)	Type	Number of Compartments
No. 1	1876	1894	Surface	5,515	500	5,015	Timber	-
No. 2	1900	1909	Surface	5,475	1,000	4,525	Timber	5
No. 3	1901	1921	Surface	5,509	1,950	3,575	Timber	3
No. 4	1910	1921	Surface	5,530	1,000	4,525	Timber	2
No. 5	1915	1953	800	4,725	3,515	2,010	Concrete	3
No. 6	1919	1953	400	5,112	3,000	2,525	Concrete	3
No. 7	1929	1953	Surface	5,210	3,000	2,525	Concrete	5
No. 8	1940	1953	2,850	2,675	4,630	895	Timber	3

When underground mining operations resumed in April 1937, unmined ore was present on every level, with more than 70% of the underground ore reserves contained within pillars and remnants. Between the surface and 1,500-foot level, unmined ore reserves occurred as remnants within partially mined stopes. From the 1,500- to the 2,250-foot level, remaining reserves were mainly confined to vertical and horizontal pillars that had been left for support. Below the 2,250-foot level, unmined ores occurred in virgin ground (Pullen, 1941).

Prior to the suspension of underground mining operations in May 1931, little attention was given to the recovery of ore contained in the mine pillars. With an abundance of ore on many levels, it was easier to develop a deeper level than dealing with pillar recovery. The dominant stoping method that had been in use at United Verde since 1908 was horizontal cut-and-fill, which was supplemented by square sets used in heavy ground. These methods were labor intensive; requiring manual shoveling of ore and hand tramming and spreading of backfill in the mined out stopes (Pullen, 1941).

When underground operations resumed in April 1937, it became apparent that mining costs could be lowered through the use of slushers and redesigning stoping methods to take advantage of gravity. Slushers were essentially a double-drum hoist attached to a scraper by a system of pulleys and cables that were employed to pull broken rock away from the mine face so it could be more easily loaded into ore cars. A modified Mitchell-slice mining method was adopted to recover pillars and remnants in the upper portion of the mine, while undeveloped ores in lower levels of the mine were extracted from inclined cut-and-fill stopes (Pullen, 1941).

Copper production declined from 85 million pounds in 1937 to 55 million pounds during 1938 and 1939, as the United Verde operation transitioned from an open pit to an underground operation and converted its coal-fired smelter to burn fuel oil. Over time the number of active mining faces in the underground operation rose, which allowed copper production to exceed 80 million pounds during 1941

and 1942 (DeWitt and Waegli, 1989). By the end of 1942, underground workings above the 1,650-foot level were abandoned due to the depletion of ore reserves.

Efforts to Stimulate Production during World War II. In an attempt to stimulate domestic production of critical minerals at the outset of World War II and avoid high prices experienced during World War I, the U. S. government instituted a premium price program for copper and other metals in January 1942. Under this program, substantial premiums were paid over established ceiling prices by the Metals Reserve Company to mining operations for production in excess of quotas that were based on their past production history (Pehrson, 1943). During the fall of 1942 and 1943, this program enabled United Verde to produce a large portion of its copper from low-grade ores, which it would not have been possible at the established copper price of 11.9 cents per pound (Woodward and Luff, 1945).

In response to the incentive of premium prices for copper during World War II, small-scale mining operations at Copper Chief, United Verde Extension and Dundee-Arizona supplied siliceous flux to United Verde's Clarkdale smelter (Anderson and Creasey, 1958). In addition to supplying custom smelting services for the district's small operators, Phelps Dodge also used its excess smelting capacity at Clarkdale to treat concentrates shipped from its Bisbee operation (Anonymous, 1981).

Exploration and Development of the North Massive Sulfide Lens. As a part of the on-going exploration efforts to evaluate the North massive sulfide lens, which had been discovered by diamond drill holes from 3,300-foot level, the No. 8 shaft was collared on the 2,850-foot level in 1940. Completed in 1942 this internal, timbered shaft had two compartments from the 2,850-foot level to the 3,300-foot level and three compartments from 3,300- to 4,630-foot level (Figure 38). A double-drum hoist located on the 3,000-foot level hoisted 3.5-ton skips to an ore pocket below the 2,850-foot level.

Separated from the main lens of massive sulfide in upper levels of the mine by the gabbro intrusive, the North massive sulfide lens was systematically explored by diamond drill holes and exploration drifts on the 3,450-, 3,750-, 4,050- and 4,500-foot levels for several years. Found to apex a short distance above the 3,450-foot level, this pipe-like zone extended vertically downward, splitting into several root-like segments before disappearing approximately 150 feet below the 4,500-foot level.

Decline and Closure of the United Verde Operation. Despite wartime demand, copper production at the United Verde operation gradually declined after recovering 86.6 million pounds during 1942. This decline resulted from a shortage of labor and depletion of ore reserves. By December 31, 1944, no mineable reserves remained above the 1,800-foot level. After several years, exploration efforts in the lower levels of mine were rewarded with the discovery of a small copper-zinc ore body during 1947. Underground development of this zone began in October 1947 (Little, 1950). Extending from the 3,750 to 4,050-foot level, the stope measured approximately 180 feet in length by 10 to 60 feet wide. Production of ores, averaging 4% copper and 9.2% zinc, commenced in June 1948, using a radial blasthole mining method that required no waste backfill (Little, 1950). These ores were hoisted to the 3,000-foot level by the No. 8 shaft and trammed to the No. 5 shaft for hoisting to the 1,000-foot main haulage level (Anderson and Creasey, 1958).

Although the Clarkdale smelter was closed on June 6, 1950, the concentrator continued to recover copper and zinc from the United Verde mine over the next several years. Copper concentrates were shipped to the Phelps Dodge's Douglas smelter, while the zinc concentrates were sold to a custom smelter in Dumas, Texas. After nearly 70 years, commercial mining operations ceased at United Verde on March 23, 1953 and the Clarkdale concentrator was closed on March 30, 1953 (Anonymous, 1981). After ceasing operations, all usable equipment and materials were salvaged from the underground workings and shipped to other operations. The concentrator was dismantled and certain properties consisting of real estate, buildings, and miscellaneous equipment were sold.

Table 9. Production from Phelps Dodge's operations at United Verde from February 19, 1935 through 1953 (DeWitt and Waegli, 1989).

Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.	Profits US \$
12,090,195	917,351,247	0	52,891,969	381,687	14,720,036	40,000,000

Over the 18-year period during which the United Verde mine was operated by Phelps Dodge nearly 12.1 million tons of ore were mined, recovering 917 million pounds of copper, 52.9 million pounds of zinc, 382,000 ounces of gold and 14.7 million ounces of silver. Profits during this period amounted to \$40 million (Table 9).

During the 70 years of underground mining at United Verde more than 83 miles of underground workings were excavated, including 304,470 feet of drifts, 123,800 feet of raises and 14,100 feet of shafts. Underground ore production totaled approximately 22.9 million tons. Between 1918 and 1940, approximately 41.8 million tons material were extracted from the open pit, including 8.2 million tons of direct smelting ore, 1.7 million tons of siliceous flux and 32 million of waste (Anderson and Creasey, 1958). Between 1883 and 1953, the United Verde operation recovered 2.9 billion pounds of copper, 52.9 million pounds of zinc, nearly 1.3 million ounces of gold and 48.1 million ounces of silver.

### **Smaller Producers (1900-1950)**

For many years, the United Verde deposit was the only producer in the Verde mining camp. The poorly understood nature of the district's mineralization provided little incentive to invest the capital required to properly evaluate the district's mineral potential. However, rich discoveries made at United Verde Extension between 1914 and 1916, combined with the increase in the price of copper at the beginning of World War I, stimulated exploration and development activities throughout the region. A map of mining claims is shown in Figure 39. In response to this flurry of activity, Jerome's population rose from 2,400 in 1910 to 10,000 by 1917 to fill the demand for workers required by the district's mines and its supporting infrastructure. Peak periods of production for the district's small producers occurred during the first and second World Wars.

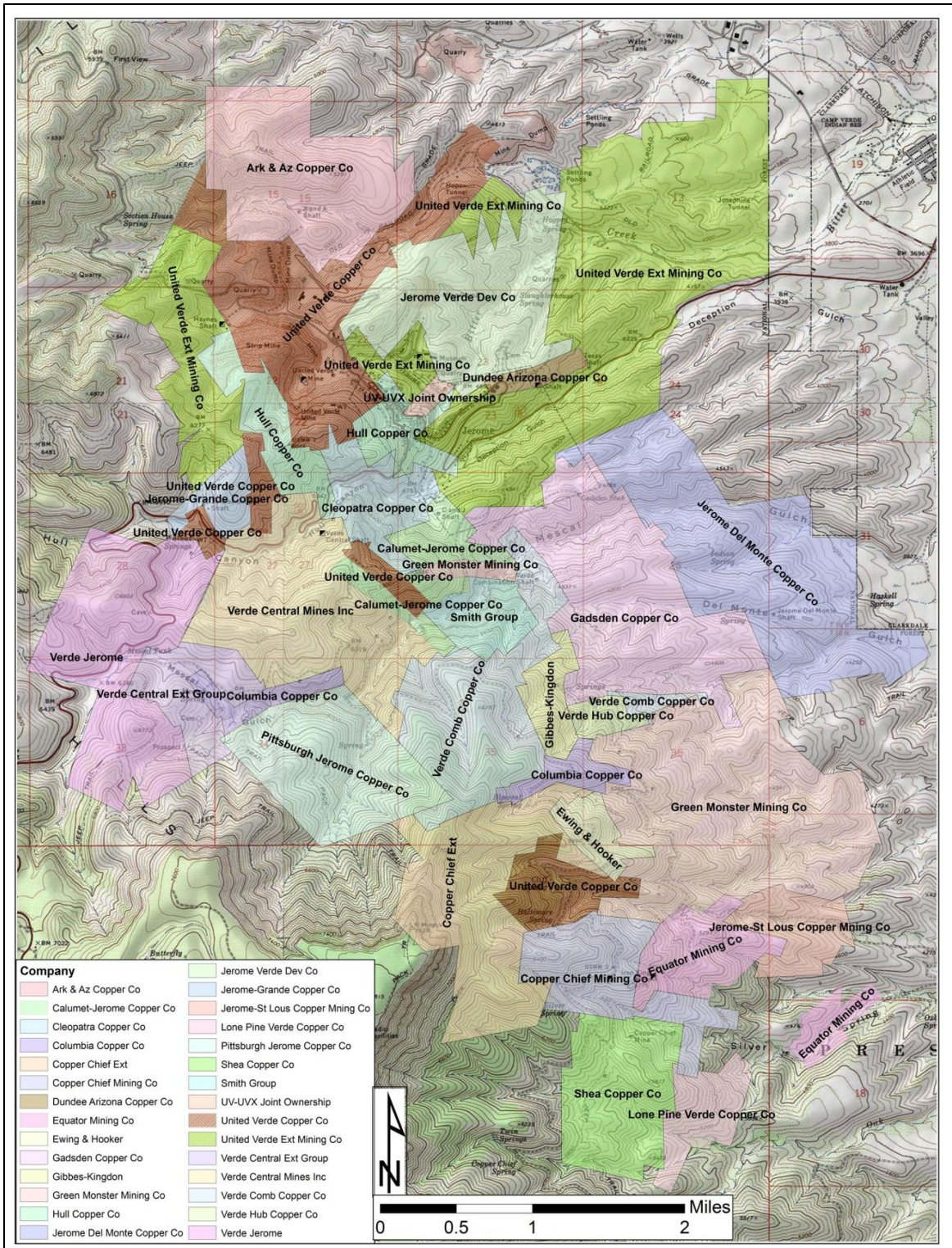


Figure 39. Map of claim holdings in the Verde Mining District. Circa 1926 (Arizona Geological Survey Mine Database).

Copper Chief Mine (1895-1948). Located about 3.5 miles south-southeast of Jerome, the Copper Chief deposit was jointly owned by the Copper Chief Mining Company and the Equator Mining and Smelting Company. The Equator Mining and Smelting Company owned the eastern half of the deposit, while the Copper Chief Mining Company held western half (Anderson and Creasey, 1958).

The eastern half of the deposit was also known as the Iron King Mine. It covered a large gossanous outcrop measuring 1,000 feet long by 600 feet wide. Originally acquired by William Clark in 1895, copper-silver ore was soon discovered at the site. The Equator Mining and Smelting Company was organized in March 1900 as a West Virginia corporation. Over the next four years, the property was developed to a depth of 300 feet. A 5,000-foot aerial tramway connected the upper mine portal with a roast-yard, which was located adjacent to a 250-ton/day smelter that began treating ore in June 1904. This short-lived operation was suspended on September 1, 1905, after recovering 1.33 million pounds of copper from 15,700 tons of sulfide ore (Tenney, 1927).

Arthur Hendy organized the Copper Chief Mining Company to work on claims located immediately west of Clark's Iron King property. Prior to 1908, a short tunnel driven beneath the discovery outcrop encountered oxidized gold-silver ore containing little copper. Further development included a 380-foot shaft with workings on the 100-, 160-, 220- and 280-foot levels. Oxidized ores from Copper Chief's property were mined primarily for its precious metals content between 1915 and 1923. Most of this production came from a small 125-ton/day cyanide mill that was operated by the Hayden Leasing Company from September 1915 through November 1918, when operations were halted due to high operating costs (Weed, 1922). Several hundred tons of sulfide ore was also shipped to the Humboldt smelter during this period. An additional 81,000 tons of oxidized siliceous flux was shipped from Copper Chief deposit to area smelters during World War II (Anderson and Creasey, 1958).

Verde Central Mine (1904-1931). Located along Hull Canyon, approximately one mile south of the United Verde Pit, the Verde Central property was initially staked in 1904 and passed through several hands before Verde Central Mines, Inc. was organized by W. F. Staunton in August, 1916 (Anderson and Creasey, 1958). Over the next eight years, an existing inclined shaft was deepened from 200 feet to 1,050 feet and explored on several levels. In June 1921, the Calumet and Arizona Mining Company purchased 1,000,000 shares of the 1,600,000 outstanding shares of Verde Central Mines, providing funding required for the on-going exploration program. Claims formerly owned by the Venture Hill Mining Company and Verde Apex Copper Mining Company were subsequently acquired expanding their holdings to 33 claims. Five additional claims of the Verde Syndicate Copper Company were purchased for \$50,000 in July 1925 (Tenney, 1927).

During early 1922, a cross-cut on the 600-foot level encountered ore that assayed 10 to 15% copper and 5 to 6 ounces of silver per ton (Weed, 1922). A new 3-compartment, vertical, production shaft was collared on February 1, 1924, and reached a depth of 1,946 feet in October 1926. Construction of a 300-ton/day concentrator began in May 28, 1928 and was commissioned on January 1, 1929 (Dickson and Smith, 1931). Copper concentrates from Verde Central's mill were custom smelted at United Verde Extension's Clemenceau smelter.

Confined between the 600-foot to 1,900-foot levels of the Verde Central Mine, most of the ore occurred along the Rock Butte zone. Individual stopes measured 50 to 300 feet in length by 5 to 40 feet in width (averaged 15 feet) with vertical dimensions being greater than lengths. Shrinkage and cut-and-fill mining methods were employed to extract the ores (Dickson, 1931).

Production was suspended at Verde Central on October 31, 1930, due to falling copper prices during the Great Depression. The Verde Central property was sold to United Verde Copper Company in July 1931 for \$250,000 (Gerry and Miller, 1934). Little additional work has been done to evaluate this resource.

Dundee Arizona Mine (1918-1947). Located along a low ridge line separating Bitter Creek and Deception Gulch, the Dundee Arizona Copper Company sank a shaft to a depth of 950 feet during 1920, in an effort to explore bedrock that is concealed by Tertiary gravels. Although little mineralization was discovered in the Precambrian section that hosts other deposits in the district, a four- to five-foot thick horizon of gravels impregnated with oxide copper (chrysocolla) was discovered at the base of the Tertiary section. Between February 1942 and July 1947, this underground operation produced approximately 100 tons of hand-sorted ore per week, averaging about 4.5% copper, which was delivered to the Clarkdale smelter (Anderson and Creasey, 1958).

### **Haynes Massive Sulfide Deposit (1906 - 1935)**

Another significant mineral occurrence in the Verde Mining District was the Haynes massive sulfide deposit. Situated at approximately 2,700 feet northwest of the United Verde mine, the Haynes deposit never produced any ores, but was the site of much exploration activity between 1906 and the early 1930s.

The Haynes Copper Company was organized in October 1907, as the successor of the Jerome Mines Development Company, which held eight patented mining claims located immediately west of United Verde Copper's property (Stevens, 1909). Haynes Copper sank a 3-compartment shaft to 1,200 feet and developed drifts and cross-cuts driven on the 700- and 1,200-foot levels before abandoning the underground workings in 1914 due to excessive flow of groundwater (Weed, 1916). In 1916, Haynes Copper was subsequently reorganized as the Jerome Victor Extension Copper Company, which dewatered the shaft to 1,200 feet by June 1917. However, a miner's strike resulted in suspension of work, allowing the shaft to flood again (Weed, 1918). The West United Verde Copper Company absorbed the Jerome Victor Extension Copper Company in October 1917, but performed little work on the property before selling it to the United Verde Extension Mining Company in November 1919 for \$250,000 (Weed, 1922).

Little work was done by United Verde Extension over the next ten years due to commitments elsewhere in the district. During the late 1920s, they decided to renew exploration efforts below the 1,200-foot level of the Haynes shaft. However, instead of re-entering the Haynes Shaft, they signed a working agreement with the United Verde Copper Company, which allowed them to access the ground by driving an exploration drift westward from the 3,000-foot level of United Verde mine. This work began in July

1930 and encountered the southern margin of the Haynes deposit in June 1931. After exploring the Haynes deposit on the 3,000-foot level, a drift on the 1,500-foot level of the United Verde mine and diamond drill holes from 3,000-foot and 3,700-foot levels delineated the size, shape and tenor of the Haynes deposit (Anderson and Creasey, 1958).

This work demonstrated the Haynes deposit was a steeply northeast, plunging, pipe-like body of massive sulfide and quartz, which extended from a short distance above the 2,700-foot level down to a point between the 3,450 and 3,700-foot levels of the United Verde mine. On the 3,000-foot level, it had a small, triangular-shaped, cross-sectional area (6,000 square feet), which diminished both upward and downward (Anderson and Creasey, 1958). The Haynes deposit appears to represent a fragment of the United Verde massive sulfide lens that was separated from the main lens by emplacement of a post-mineral gabbro sill.

### **Jerome - Recent Years (1953 - Present)**

During the years following peak production in 1929, the population of Jerome declined from 15,000 residents to approximately 1,200 in 1950. With the suspension of large scale mining operations at the United Verde mine during 1953, many of the remaining residents abandoned their homes for better opportunities elsewhere, leaving about 200 residents remaining in the community (Price, 2004). Many of its structures were demolished for materials, while the lack of maintenance and a heavy snowfall in 1967 destroyed others.

Big Hole Mining Company (1954-1975). In 1954, the Big Hole Mining Company acquired a lease from Phelps Dodge to salvage remnants of ore that remained in the pit after surface operations ceased at United Verde (O'Brien, 1991). At the time open pit operations were suspended in April 1940, there were a number of areas throughout the pit where it was not feasible for a large-scale operation to recover the ore. However, a small-scale mining operation, employing eight to twelve experienced miners was profitable.

Table 10. Production from Big Hole Mining Company's salvage operations at United Verde from 1954 through 1975 (DeWitt and Waegli, 1989).

Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
206,777	25,292,826	0	0	2,886	200,387

Recovering remnants of ore from the steep, unstable walls of the open pit with narrow ledges and numerous overhangs was extremely hazardous. Loose rock was scaled from the steep walls and zones of ore were blasted, with the debris falling to the bottom of the pit. The debris was sorted with the ore loaded into trucks for transport to a rail siding at Clarkdale, where it was loaded into rail cars provided by Phelps Dodge for transport to the Douglas smelter. During the period from 1954 through 1975, the Big Hole Mining Company extracted an additional 206,777 tons of ore from the United Verde ore body,

recovering 25.3 million pounds of copper, nearly 2,900 ounces of gold and 200,000 ounces of silver (Table 10).

Jerome's Transition to a Tourist-based Economy. As large-scale mining operations at the United Verde mine declined during the early 1950s, residents of Jerome realized that if their community was to survive, a new source of income must be found. A group of concerned citizens formed the Jerome Historical Society in March 1953 with the hope of attracting tourists interested in the area's rich mining history. In June 1953 the Jerome Historical Society opened a museum in a former drugstore and saloon, which had been leased from Verde Exploration Ltd., the successor of the United Verde Extension Mining Company. Verde Exploration later sold this building to the society for a nominal fee and in 1956 donated much of its downtown holdings to the Jerome Historical Society, which were later sold or leased to artists and businesses, who have transformed Jerome's economy from one dependent on mining into a bustling arts and craft community that caters to tourists interested in learning more about the mining camp's colorful history (Price 2004).

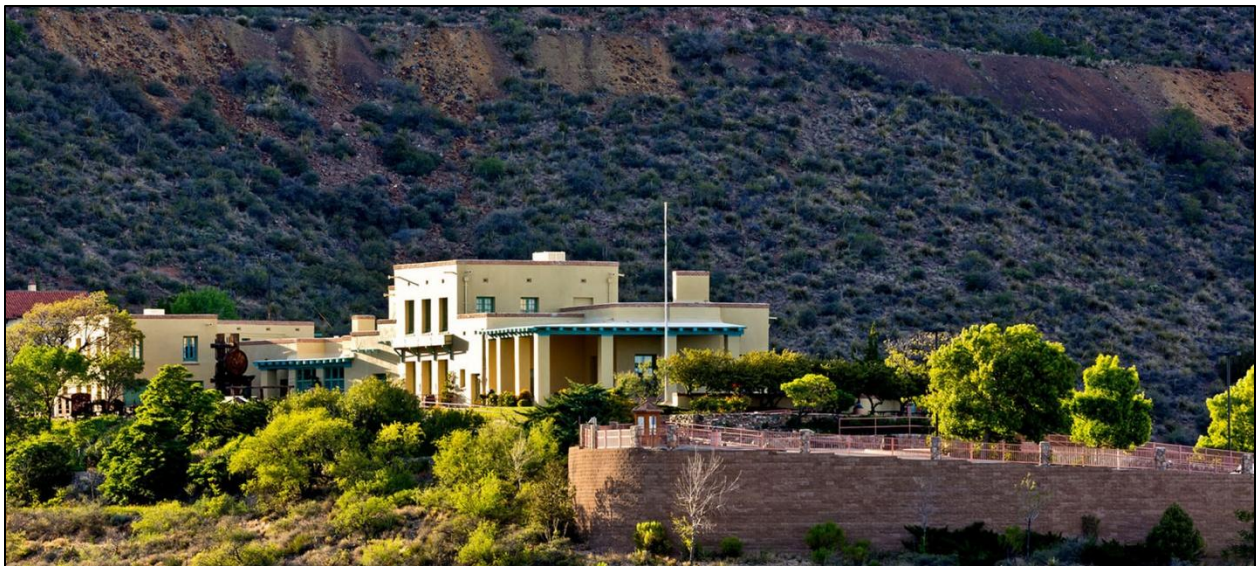


Figure 40. The visitor center at the Jerome State Historic Park was the home of James "Rawhide" Douglas, one of the principle backers of the United Verde Extension project. Now serving as the visitor center, it serves as a museum devoted to the history of mining at Jerome and the Douglas family (photo provided by Jerome State Historic Park).

In August 1957, the Jerome Historical Society contacted the Arizona State Parks Board, promoting the idea of making the town of Jerome a state monument. About the same time, the heirs of James S. Douglas were searching for a new use for the family's mansion. Both the Jerome Historical Society and the Douglas family fully supported the idea of turning it into a mining museum. Arizona State Park staff conducted a feasibility study in 1960 that concluded the Douglas mansion with its unparalleled vistas of the historical mining camp was the best site to establish a new state park. The Douglas family donated the Douglas Mansion to the State of Arizona in August 1962 (Price, 2004). Jerome State Historic Park

was dedicated and opened to the public on October 16, 1965 with James "Rawhide" Douglas' home becoming its visitor center (Figure 40).

Advances in Scientific Knowledge Provide New Exploration Opportunities. Theories about how volcanogenic massive sulfide deposits like those in the Verde Mining District formed were not fully understood by geologists until the second half of the 20th century. Prior to this time, most occurrences of this type were believed to have formed by fissure-filling and/or selective hydrothermal replacement, but the source for the hydrothermal solutions was controversial (Shanks, 2012). Post-World War II studies of weakly metamorphosed Kuroko ("black ore") ore deposits by Japanese geologists clearly showed the Miocene massive sulfide ores were related to submarine volcanism. By the mid-1960s, these genetic models were being used to evaluate similar, older, deformed, and regionally metamorphosed deposits of the Abitibi Greenstone Belt in Ontario and Quebec, Canada (Gilmour, 1965) and Iron King mine near Humboldt, Arizona (Gilmour and Still, 1968).

Prior to the early 1960s, the deposits of the Verde Mining District were believed to have been formed by the selective replacement of favorable host rocks adjacent to a quartz porphyry intrusive (Anderson and Creasey, 1958). However by the late 1960s, Paul Handverger and a number of other geologists, who had worked in the Rouyn-Noranda region in western Quebec recognized deposits in the Verde Mining District had a volcanogenic origin. Also aware of its volcanogenic origin, Dr. Charles Meyer, a professor of economic geology at the University of California, Berkeley and a consultant for the Anaconda Copper Mining Company, persuaded Anaconda to acquire an option to explore Verde Exploration's property in late 1971. This exploration project continued until early 1976 (Lindberg, 2018).

During the early 1970s, Anaconda's geological staff were visited by Lewis Douglas, a son of James "Rawhide" Douglas. Lewis Douglas served in a member of the U. S. House of Representatives representing Arizona from 1927 until 1933 and as the U. S. Ambassador to England from 1947 until 1950. In his late 70s at the time of his visit, he was arrived at Anaconda's Jerome exploration office in a chauffeured limousine. Curious to learn more about Anaconda's exploration program in the Verde Mining District, he questioned Anaconda's exploration geologists. After describing their program, one of the Anaconda geologists asked Lewis Douglas; "Why his father hadn't continued exploration efforts as the UVX operation was running out of high-grade ore, despite advice from mining engineers to continue exploring?" To paraphrase his response, "My Daddy found what he believed to be the faulted-off apex of the United Verde ore body and didn't want to spend another nickel in wasting it on fruitless exploration". Although this was sound business sense based on their understanding of the geology at the time, James S. Douglas had no knowledge of the volcanogenic massive sulfide models that evolved during the 1960s. This new understanding of how these deposits formed has generated new opportunities for future discoveries in the Verde Mining District (Lindberg 2018).

Gold Production from the United Verde Extension. With the rapid rise in the price of gold during late 1979 and 1980, interest was renewed in mining the reserves that remained in the "Gold Stope", when United Verde Extension mine closed in 1938. Verde Exploration Ltd. initially leased the property to Phelps Dodge in 1981. Phelps Dodge replaced the wooden headframe of the Edith Shaft with a surplus steel headframe and single-drum electric hoist from its Bisbee property and rehabilitated the shaft.

After reopening the upper levels of the mine, they drilled two holes, totaling approximately 1,000 feet before dropping their lease in 1983, after exploration results suggested their goal of delineating 1 to 2 million tons gold-bearing siliceous flux, averaging 0.1 to 0.2 oz. Au/ton was not likely (White, 1986).

Verde Exploration Ltd. leased the property to A. F. Budge Mining Ltd. in April 1985. After several years of underground exploration and development, limited underground production was achieved in February 1989. Mined at a rate of approximately 50 tons/day, a silica-rich flux, containing 0.1 to 0.25 oz. Au/ton, was delivered via truck to a railhead at Clarkdale for trans-shipment to the Phelps Dodge's Hidalgo smelter in New Mexico. This operation was terminated in late 1992 after recovering approximately 21,000 ounces of gold and 174,000 ounces of silver from about 76,000 tons of ore (Table 11).

Table 11. Production from A. F. Budge's operations at United Verde Extension from 1989 through 1992 (Arizona Geological Survey Data).

Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
76,312	49,156	0	0	20,876	174,233

Evaluation of United Verde's Zinc Resource. When mining ceased at the United Verde property in 1953, a large zinc resource remained at the site. Based on a 4% zinc cut-off, 21 million tons of material has been identified between the 500- to 3,000-foot levels, which averages 0.52% copper, 6.6% zinc, 0.020 oz. Au/ton and 0.62 oz. Ag/ton (DeWitt and Waegli, 1989).

Since its closure, the potential of resuming operations at United Verde has been evaluated by several companies, including Boliden (?) and Billiton Exploration during the early 1980s (White, 1989). The most recent evaluation began in late 1994, when Cominco Ltd. acquired an option to earn a 51% interest in the United Verde property by spending \$6 million on exploration and development. After re-establishing access through the Hopewell tunnel, an underground diamond drilling program was conducted over a period of several years. Cominco suspended its evaluation at United Verde in 1999 without releasing the results of this program.

### **Clarkdale - Recent Years (1953 - Present)**

In October 1953, the Phelps Dodge Corporation sold the Clarkdale town site, smelter and Upper Verde Utility Company to W. L. Allison, who commenced salvage operations at the smelter site. Allison subsequently sold these properties to Erle P. Halliburton, who had made a fortune in the oilfield service industry in Oklahoma during the early 1900s (Farley, 2015). He continued salvage operations at the closed smelter and become the landlord for nearly every resident in the town. Halliburton sold some of Clarkdale's residential property, allowing residents to become property owners for the first time (Hutchinson, 2008). The town of Clarkdale was incorporated in July 1957.

Following Halliburton's death in October 1957, William Zeckendorf, president of Webb and Knapp acquired the smelter site, including the slag pile, in 1958 for \$1.4 million. Zeckendorf was the grandson of William Zeckendorf, a prominent Tucson merchant and mine speculator during the latter half of the nineteenth century. Halliburton's remaining real estate holdings were auctioned off during the summer of 1959 for \$1.15 million to Westfield Corporation, which served as an agent for Webb and Knapp (Anonymous, 2014).

In September 1959, Webb and Knapp announced plans to erect a \$15 million steel mill at the former Clarkdale smelter site. Existing homes would be renovated and sold. They planned to use the remaining site infrastructure to establish a steel mill that would employ the Udy Process to produce steel from copper slag (Burke, 1959). Over its 30-year projected life, this project would employ 200 to 300 workers. Designed to produce 500 tons of steel daily, it would also be capable recovering most of the copper and zinc as by-products. Residue from this process could be used to manufacture insulation and lightweight aggregate used in concrete (Anonymous, 2014).

Webb and Knapp canceled its plans for a steel mill at Clarkdale in December 1960, deciding instead to build their facility in Anaconda, Montana (Hutchinson, 2008). United Verde Copper Company's 400-foot steel smoke stack at its Clarkdale smelter was demolished in July 1962, while its 430-foot brick smoke stack was toppled by a controlled blast in October 1966 (Handverger and Clarkdale Historical Society, 2014).

The Phoenix Cement plant commenced operations at Clarkdale in October 1959. It was built to supply cement to the Glen Canyon Dam project near Page, Arizona. Today, it continues to meet the demand for cement products in Phoenix and northern Arizona (Wright, 2009). Since 1990, the old Verde Valley rail line has been used by the Verde Canyon Railroad, which provides a popular attraction for tourists to view the spectacular scenery along the Verde River Canyon between Clarkdale and Perkinsville.

## **Reclamation Activities**

As with many historical mine sites throughout the West that operated prior to the enactment of modern environmental legislation, the Verde Mining District has required special efforts to protect surface and groundwater resources from the impacts of acid mine seepage and storm water run-off from acid generating waste rock dumps.

During Verde Mining District's early history, much of the native vegetation in the mountains around Jerome was denuded by overharvesting and uncontrolled emissions from roasting and smelting operations. Without soil-securing roots from this vegetation, the town was susceptible to mud and debris swept down the mountain slopes by heavy storm run-off. In an effort to resolve this problem, forty pounds of Tree-of-Heaven (*Ailanthus altissima*) seeds were air-seeded over the mountainside during the mid-1960s with the idea this non-native, pollution-tolerant tree would stabilize the slopes above Jerome. However, the seeds failed to take root on the barren hillsides. Later run-off from heavy rainstorms carried the seeds into town, where growing conditions were more favorable. Once mature,

the *Ailanthus* trees reproduced quickly, spreading down the washes into the Verde Valley, overwhelming the native plant species (McCarthy, 2014).

Remediation in the Verde Mining District has involved work at the United Verde and Copper Chief mine sites and at the Clarkdale tailings impoundment. Phelps Dodge began working on this project in 1994. This remediation effort required many years of planning and permitting from numerous state and federal agencies. Frequent meetings were also held with officials of Jerome, encouraging an open dialogue regarding residents' concerns and ideas (Anonymous, 2009 ?).

Since the closure of the concentrator at Clarkdale in 1953, the tailings impoundment located in an abandoned channel and oxbow lake along the Verde River has been a major source of wind-blown dust that has plagued Verde Valley. From the early 1950s until the 1980s, Phelps Dodge pumped water from Peck's Lake to wet the surface of the tails to reduce airborne dust. Beginning during the 1980s, the town of Clarkdale pumped effluent from its wastewater treatment facility over the top of the tailings (Beisner, et. al, 2014).

Phelps Dodge began reclamation work on the 129-acre tailings impoundment during the spring of 2006. Completed in 2007, this project included capping the tails with natural soil cover and reseeding the site with native plants and grasses. This remediation was designed to minimize seepage of heavy metals into the groundwater by absorbing the rainfall, allowing it to evaporate or be used by the vegetation through the process of evapotranspiration. Rock-lined channels collect storm water and divert it around the capped area (Anonymous, 2008). Before and after reclamation photos of the Clarkdale tailings site are shown in Figure 41.

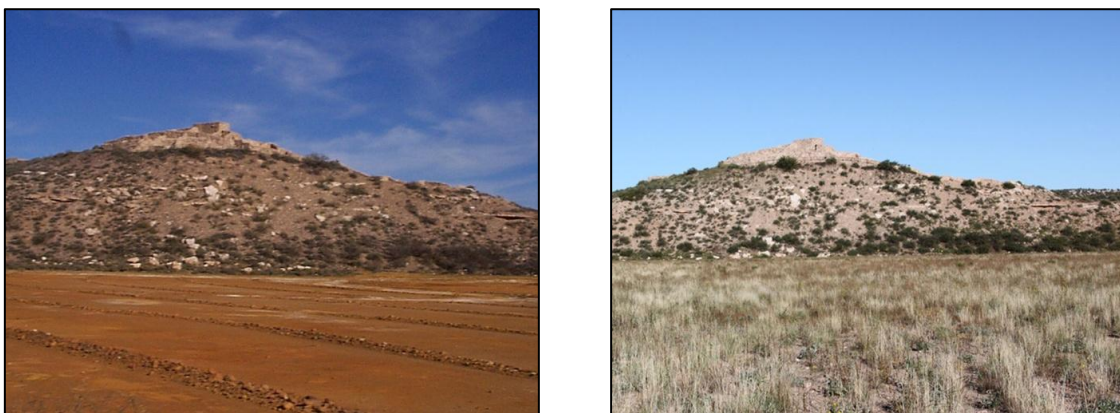


Figure 41. Tuzigoot National Monument with Clarkdale tailings Impoundment in foreground, before (left) and after reclamation (right) (photo provided by the National Park Service).

Phelps Dodge's successor, Freeport-McMoRan Copper and Gold, Inc. (renamed Freeport-McMoRan, Inc. in July 2014) capped glory holes and mine dumps with soil and reseeded with native vegetation at the Copper Chief mine during 2007. A passive water management system designed to control seepage from the mine workings was installed during 2009. The seepage is treated in lined ponds, where wood chips, lime and other organic material are used to precipitate the contained metals (Gusek and Buchanan, 2009).

Freeport-McMoRan commenced a major remediation program at the United Verde site in October 2007. This project included the construction of a 1.5-mile storm water diversion channel around disturbed areas of the United Verde mine site and a clean water channel below the Hopewell tunnel. Acid-generating mine dumps in the United Verde mine and Hopewell tunnel areas were graded and covered with an evapotranspirative cap. This reduces acid rock drainage by preventing storm water from contacting acid-generating material contained in the mine dumps (Anonymous, 2009 ?).

Several seepage and lined evaporation impoundments were constructed below the former 500-foot level plant site to deal with contaminated run-off that could not be diverted due to logistical challenges. A 300-foot gravity drain-hole was installed in this area to redirect seepage into the underground mine workings. The seepage eventually discharges through the Hopewell tunnel into a series of treatment channels and lined evaporation impoundments (Figure 42). A clean water channel was constructed below the Hopewell tunnel to conduct uncontaminated water through the project area and off-site into a natural drainage (Anonymous, 2009 ?).



Figure 42. Before and after photos showing acid mine drainage containment at the Hopewell tunnel site (photo provided by Freeport-McMoRan, Inc.).

In cooperation with the town of Jerome, Freeport-McMoRan paved a parking lot on the 300-foot level mine dump to accommodate tourists on whom the community's economy now depends. They also

added an emergency helipad at that site to provide a safe landing zone within the town limits. Freeport-McMoRan also replaced Jerome's main water supply line from the town's main storage tanks as well as water and sewer lines on the 300-foot level (Anonymous, 2009 ?).

Charitable contributions from Freeport-McMoRan helped renovate Jerome's historic school house, which now serves as the town's new library. The Jerome Historical Society benefited from Freeport-McMoRan's assistance in developing story boards that explain the historical significance of various sites throughout the community. Freeport-McMoRan also supported the preservation of Jerome's unique and colorful mining history by donating a scale model of the district's underground mine workings and historical artifacts to the Jerome State Historic Park (Anonymous, 2009 ?).

While the slag dump adjacent the Clarkdale smelter site remains undisturbed, Mineral Research and Recovery, Inc. has been harvesting and recycling slag from the Clemenceau smelter site for the roofing, abrasives and asphalt industry since 2015 (Jernigan, 2017).

## **Future of Verde Mining District**

Mining activities are comprised of four basic stages: discovery, development, mining, and reclamation. This cycle is not a linear progression from discovery to depletion, but may consist of many iterations resulting from a complex interplay of geology, technology, public policy and market forces that extend the productive life of a mining operation. In some cases, production from ore deposits may cease and the mine be reclaimed only to be redeveloped much later as new technologies become available (Long, 2008).

The main period of production from the Verde Mining District occurred prior to the closure of the United Verde operation in 1953. During this period, the United Verde operation faced many challenges (i.e. remote location, unstable ground and mine fires) that were met and overcome as ores were gradually developed and mined at greater depths. As the district's geology became better understood, discoveries by the United Verde Extension Mining Company between 1914 and 1916 and the increased demand for copper at the onset of World War I spurred exploration activities throughout the Verde Mining District, leading to the development and limited production from the Verde Central, Copper Chief, Dundee-Arizona and other properties.

Since the suspension of commercial operations at the United Verde mine in 1953, small-scale, salvage operations at the United Verde and UVX mines extracted ores that were unprofitable for the larger producers to recover. As in other famous mining camps (i.e. Bisbee, Arizona and Virginia City, Nevada), Jerome's economic base transitioned from mining to a bustling arts and craft community during this period. The community now caters to tourists, who are interested in learning more about the mining camp's colorful history. Mining activities have remained dormant, with the last recorded production occurring during the early 1990s.

Resumption of mining activities in the Verde Mining District remains uncertain. The most obvious resource occurs at the United Verde mine, where approximately 21 million tons of material has been identified between the 500- and 3,000-foot levels, averaging 0.52% copper, 6.6% zinc, 0.020 oz. Au/ton, and 0.62 oz. Ag/ton (DeWitt and Waegli, 1989). However, metallurgical tests show these ores require extremely fine grinding, requiring it to pass 800-mesh to obtain 90% liberation of copper and zinc minerals from the pyrite. With the best zinc grades remaining between the unstable hanging wall gabbro and backfilled stopes along the footwall, much of the zinc resource has slowly subsided due to compaction of the backfill in the previously mined stopes. This subsidence will complicate any future extraction of the remaining zinc resource at United Verde (Anderson and Creasey, 1958).

Mineral exploration of Verde Mining District has been intermittent since the closure of United Verde operation in the early 1950s. Prior to this time, exploration activities were based on genetic models that assumed these deposits were formed by the selective replacement of favorable host rocks adjacent to a quartz porphyry intrusive (Anderson and Creasey, 1958). However, using results of subsequent geologic studies that evolved during the late 1960s and early 1970s, Anderson and Nash (1972) reinterpreted the intrusive body in the footwall of the United Verde deposit to be an extrusive crystal tuff and conclusively demonstrated these ores were related to submarine volcanism and deposited adjacent to hydrothermal vents on the sea floor.

This new knowledge can be applied to future exploration programs. The restriction of the massive sulfide occurrences to specific stratigraphic intervals within the volcanic sequence (i.e. top of the Deception Rhyolite and lower member of Cleopatra Rhyolite) and the distinct spatial distribution of their metal and alteration suites are valuable tools that can be used to evaluate the district's future mineral potential.

Although past exploration activities have already examined outcropping and near surface targets, much work remains to be done in re-evaluating these areas in light of the new understanding gained from recent regional geological mapping programs and the practical application of volcanogenic massive sulfide models. Full delineation of the massive sulfide-bearing horizon at the top of the Deception Rhyolite in the Verde Central mine is incomplete and poorly understood. Potential concealed extensions of the Copper Chief deposit that have been displaced by post-mineral faulting remain unevaluated and represent viable exploration targets (Lindberg, 1986b). Future evaluation of these areas as well as other concealed exploration targets will depend on budgetary priorities that are based on potential economic benefits projected from possible future discoveries in the Verde Mining District compared to discoveries made elsewhere.

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## References

- Alenius, E. M. J., 1930, Methods and Costs of Stripping and Mining at the United Verde Open-Pit Mine, Jerome, Arizona: U. S. Bureau of Mines Information Circular 6248, 35 p.
- Alenius, E. M. J., 1968, A Brief History of the United Verde Open Pit, Jerome, Arizona: Arizona Bureau of Mines Bulletin 178, 34 p.
- Anderson, C. A., and Creasey, S. C., 1958, Geology and Ore Deposits of the Jerome Area, Yavapai County, Arizona: U. S. Geological Survey Professional Paper 308, 185 p.
- Anderson, C. A., and Nash, J. T., 1972, Geology of the Massive Sulfide Deposits at Jerome, Arizona - A Reinterpretation: *Economic Geology*, v. 67, n. 7, p. 845-863.
- Anderson, L., 1936, Railroad Transformation through Prescott: *Arizona Historical Review*, v. 7, n. 3, p. 55-72.
- Anderson, P., 1989, Proterozoic Plate Tectonic Evolution of Arizona, *in* *Geologic Evolution of Arizona*: J. P. Jenney and S. J. Reynolds (eds.), *Arizona Geological Society Digest* 17, p. 17-55.
- Anonymous, 1888, Clark's New Copper Deal: *Mining and Scientific Press*, v. 60, n. 14, p. 221.
- Anonymous, 1911, Roasting Copper Ore: *The Technical World Magazine*, v. 15, n. 4, p. 485.
- Anonymous, 1918a, Tall Chimneys in Metallurgical Plants: *Engineering and Mining Journal*, v. 106, n. 4, p. 168-171.
- Anonymous, 1918b, Photographs from the Field: *Engineering and Mining Journal*, v.106, n. 25, p. 1078-1079.

- Anonymous, 1930, Senator Clark, the Pioneer, A Biographical Sketch of William A. Clark, *in* United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 2-3.
- Anonymous, 1981, Jerome Produced Three Fortunes in Copper, *in* Phelps Dodge, a Copper Centennial 1881-1981: Supplement to Arizona, Pay Dirt, Summer 1981, p. 82-108.
- Anonymous, 2008, Mining Reclamation in Arizona: Freeport-McMoRan Copper and Gold, Inc. Brochure, 15 p.
- Anonymous, 2009 (?), The United Verde Mine Project: Preserving an Arizona Treasure: Freeport-McMoRan Gold and Gold, Inc. Brochure, 11 p.
- Anonymous, 2014, [1959: Clarkdale; \\$15 million Steel Mill Planned, September:](https://www.verdenews.com/news/2014/sep/26/1959-clarkdale-15-million-steel-mill-planned-sept/) Verde Independent, September 26, 2014, (<https://www.verdenews.com/news/2014/sep/26/1959-clarkdale-15-million-steel-mill-planned-sept/>).
- Anonymous, 2017a, [U.S. v. United Verde Copper Co., \(1905\)](http://caselaw.findlaw.com/us-supreme-court/196/207.html): Find Law for Legal Professionals, (<http://caselaw.findlaw.com/us-supreme-court/196/207.html>).
- Anonymous, 2017b, [United Verde and Pacific Railway](https://en.wikipedia.org/wiki/United_Verde_%26_Pacific_Railway): Wikipedia, ([https://en.wikipedia.org/wiki/United\\_Verde\\_%26\\_Pacific\\_Railway](https://en.wikipedia.org/wiki/United_Verde_%26_Pacific_Railway)).
- Anonymous, 2017c, [Clarkdale, Arizona](https://en.wikipedia.org/wiki/Clarkdale,_Arizona): Wikipedia, ([https://en.wikipedia.org/wiki/Clarkdale,\\_Arizona](https://en.wikipedia.org/wiki/Clarkdale,_Arizona)).
- Anonymous, 2018, Mineral Commodity Summaries 2018: U. S. Geological Survey, 200 p.
- Ascarza, W., 2014, Mine Tales: Tiny Jerome was Once One of the World's Biggest Names in Copper Production: Arizona Daily Star, April 21, 2014.
- Ayers, S., 2010, [A Brief History of Verde River Cartography](https://www.cvbugle.com/news/2010/jan/19/a-brief-history-of-verde-river-cartography/): Camp Verde Bugle, January 19, 2010, (<https://www.cvbugle.com/news/2010/jan/19/a-brief-history-of-verde-river-cartography/>).
- Barker, L. M., 1930, Concentrating Plant of United Verde Copper Company, *in* United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 65-69.
- Beisner, K. R., Paretti, N. V., Brasher, A. M. D., Fuller, C. C., and Miller, M. P., 2014, Assessment of Metal and Trace Element Contamination in Water, Sediment, Plants, Macroinvertebrates, and Fish in Tavasci Marsh, Tuzigoot National Monument, Arizona: U. S. Geological Survey Scientific Investigations Report 2014-5069, 72 p.
- Braatz, T., 2003, Surviving Conquest, A History of the Yavapai Peoples: University of Nebraska Press, 305 p.
- Briggs, D. F., 2018, Unpublished data.
- Brogdon, J. C., 1952, The History of Jerome, Arizona: M.A. Thesis, University of Arizona, Tucson, Arizona, 161 p.

- Burke, J. J., 1959, Udy Process Applied to Copper Slags: *Journal of Metals*, v. 11, n. 12, p. 829.
- Clements, E. L., 2003, *After the Boom in Tombstone and Jerome, Arizona, Decline in Western Resource Towns*: University of Nevada Press, Reno, Nevada, 395 p.
- D'Arcy, R. L., 1930, Mining Practice and Methods at the United Verde Extension Mining Company, Jerome, Arizona: U. S. Bureau of Mines Information Circular 6250, 32 p.
- DeWitt, E., and Waegli, J., 1989, Gold in the United Verde Massive Sulfide Deposit, Jerome, Arizona, *in* Gold Deposits in Metamorphic Rocks - Part 1: United States Geological Survey Bulletin 1857-D, p. D1-D26.
- Dickson, R. H., 1931, Mining Methods and Costs of Mining Copper Ore at the Verde Central Mines, Inc., Jerome, Arizona: U. S. Bureau of Mines Information Circular 6464, 21 p.
- Dickson, R. H., and Smith, E. M., 1931, Milling Methods and Costs at the Verde Central Concentrator, Jerome, Arizona: U. S. Bureau of Mines Information Circular 6489, 16 p.
- Dorich, T. J., 1997, "This is a Tough Place to Work" Industrial Relations in the Jerome Mines, 1900-1922: *Journal of Arizona History*, v. 38, n. 3, p. 233-256.
- Douglas, Jr., James, 1885, The Cupola Smelting of Copper in Arizona, *in* Mineral Resources of the United States, 1883-1884: United States Geological Survey, p. 397-410.
- Edgerton, K., 2014, [William Clark, The Copper King](https://mtprof.msun.edu/Spr2014/edger.html): The Montana Professor, v. 24, n. 1, (<https://mtprof.msun.edu/Spr2014/edger.html>).
- Farley, G., 2015, [Verde Heritage: 1958-1960: Clarkdale Owned by William Zeckendorf](https://www.verdenews.com/news/2015/jul/20/verde-heritage-1958-1960-clarkdale-owned-by-willi/): Verde Independent, July 20, 2015, (<https://www.verdenews.com/news/2015/jul/20/verde-heritage-1958-1960-clarkdale-owned-by-willi/>).
- Farley, G., 2016, [Verde Heritage: 1916-1937: The U. V. X. Smelter](https://www.verdenews.com/news/2016/nov/04/verde-heritage-1916-1937-uvx-smelter/): Verde Independent, November 4, 2016, (<https://www.verdenews.com/news/2016/nov/04/verde-heritage-1916-1937-uvx-smelter/>).
- Gerry, C. N., and Miller, T. H., 1934, Gold, Silver, Copper, Lead, and Zinc in Arizona, *in* Mineral Resources of the United States 1931: U. S. Bureau of Mines, Part 1 - Metals, p. 377-415.
- Gilley, E., 1999, [The First Railroad and the "Battle for Prescott"](http://archive.li/cNYys): Sharlot Hall Museum, January 24, 1999. (<http://archive.li/cNYys>)
- Gilmour, P., 1965, The Origin of Massive Sulphide Mineralization in the Noranda District, Northwestern Quebec: *Geological Association of Canada Proceedings*, v. 16, p. 63-81.
- Gilmour, P., and Still, A. R., 1968, The Geology of the Iron King Mine, *in* Graton Sales Ore Deposits of the United States: J. D. Ridge (ed.), American Institute of Mining, Metallurgy, and Petroleum Engineers, Inc., New York, v. 2, p. 1238-1257.

- Greeley, M. N., 1987, The Early Influence of Mining in Arizona, *in* History of Mining in Arizona: J. M. Canty and M. N. Greeley (eds.), Mining Club of the Southwest Foundation, Volume 1, Chapter 2, p. 13-50.
- Griffing, C., 2012, Valley of the Sinagua, *in* Echoes Montezuma Well, Montezuma Castle National Monument and Tuzigoot National Monument: National Park Service, Park News and Visitor Guide, v. 6, n. 1, p. 5.
- Gusek, J., and Buchanan, R., 2009, Bio-Treatment of Mining Influenced Water: Iron King/Copper Chief Mine, Yavapai County, Arizona: Mine-Water Treatment Workshop, Eastern Arizona College, October 7-9, 2009, 34 p.
- Gustin, M. S., 1988, A Petrographic, Geochemical and Stable Isotope Study of the United Verde Orebody and Its Associated Alteration, Jerome, Arizona: Ph.D. Dissertation, University of Arizona, 261 p.
- Handverger, P. A., and Clarkdale Historical Society, 2014, Images of America Clarkdale: Arcadia Publishing, Mt. Pleasant, South Carolina, 128 p.
- House, P. K., and Pearthree, P. A., 1993, Surficial Geology of the Northern Verde Valley, Yavapai County, Arizona: Arizona Geological Survey Open File Report, OFR-93-16, 20 p.
- Hutchinson, J., 2008, [The Story of Clarkdale, the Rise and Fall of Smelter Industry is Inextricably Tied to Town's History](https://www.verdenews.com/news/2008/feb/12/the-story-of-clarkdale/): Verde Independent, February 12, 2008, (<https://www.verdenews.com/news/2008/feb/12/the-story-of-clarkdale/>).
- Irvin, G. W., 1987, A Sequential History of Arizona Railroad and Mining Development 1864-1920, *in* History of Mining in Arizona: J. M. Canty and M. N. Greeley (eds.), Mining Club of the Southwest Foundation, Volume 1, Chapter 11, p. 253-278.
- Jernigan, Z., 2017, [Company Tackles City Slag Pile](http://www.journalaz.com/news/cottonwood/7091-company-tackles-city-slag-pile.html): Journalaz.com, April 26, 2017, (<http://www.journalaz.com/news/cottonwood/7091-company-tackles-city-slag-pile.html>)
- Keefe, P. C., 1930, Smelter Crushing Plant, *in* United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 63-64 and 69-70.
- Keith, S. B., and Swan, M. M., 1995, Tectonic Setting, Petrology and Genesis of the Laramide Porphyry Copper Cluster and Arizona, Sonora and New Mexico, *in* Porphyry Copper Deposits of the American Cordillera: F. W. Pierce and J. G. Blom (eds.), Arizona Geological Society Digest 20, p. 339-346.
- Keith, S. B., 2017, Personal Communication.
- Kruse, H. V., 1930, Mine Surface Plant at the United Verde Mine, *in* United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 46-47.

- Lanning, J. E., 1930, Historical Growth of the United Verde Smelting Plant at Clarkdale, Arizona; *in* : United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 56-62.
- Lindberg, P. A., 1986a, A Brief Geologic History and Field Guide to the Jerome District, Arizona, *in* Geology of Central and Northern Arizona: J. D. Nations, C. H. Conway and G. A. Swann (eds.), Geological Society of America Field Trip Guidebook, Rocky Mountain Section Meeting, Flagstaff, Arizona, p. 127-139.
- Lindberg, P. A., 1986b, Geology of the Copper Chief Mine, Jerome District, Arizona, *in* Frontiers in Geology and Ore Deposits of Arizona and the Southwest: B. Beatty and P. A. K. Wilkinson (eds.), Arizona Geological Society Digest 16, p. 343-349.
- Lindberg, P. A., 1989, Precambrian Ore Deposits of Arizona, *in* Geologic Evolution of Arizona: J. P. Jenney and S. J. Reynolds (eds.), Arizona Geological Society Digest 17, p. 187-210.
- Lindberg, P. A., 1992, Geology and Ore Deposits of the Verde Mining District, Jerome, Arizona: Society for Mining, Metallurgy, and Exploration, Inc., SME Annual Meeting , Phoenix, Arizona, February 24-27, 1992, Preprint 92-21, 4 p.
- Lindberg, P. A., 2008, Early Proterozoic Volcanogenic Massive Sulfide Ore Deposits, Jerome, Arizona, USA, *in* Ore and Orogenesis: Circum-Pacific Tectonics, Geologic Evolution, and Ore Deposits: J. E. Spencer and S. R. Titley (eds.), Arizona Geological Society Digest 22, p. 601-610.
- Lindberg, P. A., 2018, Personal Communication.
- Lindberg, P. A., and Jacobson, H. S., 1974, Economic Geology and Field Guide of the Jerome District, Arizona, *in* Geology of Northern Arizona, Part II, Area Studies and Field Guides: Geological Society of America, Rocky Mountain Section Meeting, Flagstaff, Arizona, p. 794-804.
- Lindholm, M. S., 1991, Evolution of the Major Structure that Controls Massive Sulfide Distribution at Jerome, *in* Proterozoic Geology and Ore Deposits of Arizona: K. E. Karlstrom (ed.), Arizona Geological Society Digest 19, p. 261-270.
- Little, W. W., 1950, Radial Blastholes for Drilling an Irregular Ore Body: Mining Engineering, v. 2, n. 4, p. 463-465.
- Long, K. R., 2008, Economic Life-Cycle of Porphyry Copper Mining, *in* Ores and Orogenesis: Circum-Pacific Tectonics, Geologic Evolution and Ore Deposits: J. E. Spencer and S. R. Titley (eds.), Arizona Geological Society Digest 22, p. 101-110.
- McCarthy, M. A., 2014, Reading Arizona's Verde Valley: Agri-Ecology, Industry, Landscape Change, and Public History, 1864-2014: MA Thesis, Northern Arizona University, 229 p.

- Menges, C. M., and Pearthree, P. A., 1989, Late Cenozoic Tectonism in Arizona and Its Impact on Regional Landscape Evolution, *in* Geologic Evolution of Arizona: J. P. Jenney and S. J. Reynolds (eds.), Arizona Geological Digest 17, p. 649-680.
- Mitke, C. A., 1920, Mining Methods of United Verde Extension Mining Co.: Transactions of the American Institute of Mining and Metallurgical Engineers, v. 61, p. 188-200.
- Mills, C. E., 1925, Mining Methods of Verde District, Arizona: Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers, v. 72, p. 381-423.
- Mills, C. E., 1934, Ground Movement and Subsidence at the United Verde Mine: Transactions of the American Institute of Mining, Metallurgical and Petroleum Engineers, v. 109, p. 153-172.
- O'Brien, C. A., 1991, Jerome - A Mining Legacy in the Black Hills of Central Arizona, *in* History of Mining in Arizona: J. M. Canty and M. N. Greeley (eds.), Mining Club of the Southwest Foundation, Volume 2, Chapter 4, p. 75-107.
- O'Rourke, D. J., 1918, Tunnel Driving at United Verde Extension: Mining and Scientific Press, April 27, 1918, p. 21-22.
- Pehrson, E. W., 1943, Review of the Minerals Industries in 1942, *in* Minerals Yearbook 1942: U. S. Bureau of Mines, C. E. Needham (ed), p. 1-23.
- Peterson, H., 2009, [The Killer Flu of 1918 - How the Verde Valley Stared Down a Pandemic](https://www.cvbugle.com/news/2009/oct/20/the-killer-flu-of-1918/): Camp Verde Bugle, October 20, 2009, (<https://www.cvbugle.com/news/2009/oct/20/the-killer-flu-of-1918/>).
- Price, J. M., 2004, Gateways to the Southwest: the Story of Arizona State Parks: University of Arizona Press, Tucson Arizona, 242 p.
- Pullen, J. B., 1941, Modified Mining Methods in the United Verde Mine: American Institute of Mining and Metallurgical Engineers, Mining Technology, v. 5, n. 1, p. 1-18.
- Ralston, O. C., 1930, Research at the United Verde, *in* The United Verde Copper Company: Reprinted from the Mining Congress Journal, p. 86-87.
- Rickard, F. R., 1987, History of Smelting in Arizona, *in* History of Mining in Arizona: J. M. Canty and M. N. Greeley (eds.), Mining Club of the Southwest Foundation, Volume 1, Chapter 9, p. 191-228.
- Rickard, T. A., 1918, The Story of the U.V.X. Bonanza - I: Mining and Scientific Press, v. 116, n. 1, p. 9-17.
- Rickard, T. A., 1932, A History of American Mining: AIME Series, McGraw-Hill Book Company, Inc., 419 p.
- Rodda, J., and Smith, N. R., 1990, Experience Jerome, The Moguls, Miners and Mistresses of Cleopatra Hill: A. Caillou (ed.) Thorne Enterprises, Inc., Sedona, Arizona, 63 p.

- Shanks III, W. C. P., 2012, Historical Evolution of Descriptive and Genetic Knowledge and Concepts, *in* Volcanogenic Massive Sulfide Occurrence Model: W. C. P. Shanks III and R. Thurston (eds.), U. S. Geological Survey Scientific Investigations Report 2010-5070-C, Chapter 3, p. 23-32.
- Slack, J. F., Grenne, T., Bekker, A., Rouxel, O. J., and Lindberg, P. A., 2007, Suboxic Deep Seawater in the Late Paleoproterozoic: Evidence from Hematitic Chert and Iron Formation Related to Seafloor-Hydrothermal Sulfide Deposits, Central Arizona, USA: *Earth and Planetary Science Letters*, v. 255, n. 1-2, p. 243-256.
- Smith, H. D., and Sirdevan, W. H., 1922, Mining Methods and Costs at the United Verde Mine: *Transactions of the American Institute of Mining and Metallurgical Engineers*, v. 66, p. 127-181.
- Stevens, H. J., 1902, *The Copper Handbook, A Manual of the Copper Industry of the United States and Foreign Countries for 1901*: v. 2, Houghton, Michigan, U.S.A., 416 p.
- Stevens, H. J., 1904, *The Copper Handbook, A Manual of the Copper Industry of the World for 1903*: v. 4, Houghton, Michigan, U.S.A., 778 p.
- Stevens, H. J., 1909, *The Copper Handbook, A Manual of the Copper Industry of the World*: v. 9, Houghton, Michigan, U.S.A., 1628 p.
- Stevens, H. J., 1911, *Copper Handbook, A Manual of the Copper Industry of the World*: v.10, Houghton, Michigan, U.S.A., 1902 p.
- Tally, R. E., 1917, Mine-Fire Methods Employed by the United Verde Copper Co.: *Transactions of the American Institute of Mining Engineers*, v. 55, p. 186-202.
- Tally, R. E., 1932, Fighting fire with Steam Shovels - A Unique Operation at the United Verde, *in* *Choice of Methods in Mining and Metallurgy: A Record of Experience in Making Engineering Decisions*: American Institute of Mining and Metallurgical Engineers Series, v. 1, p. 50-55.
- Tenney, J. B., 1927, *History of Mining in Arizona*: Arizona Bureau of Mines, v. 1, Text, 403 p., v. 2 Appendix (Charts), 115 p.
- Trennert, R. A., 1999, Aerial Mine Tramways in Arizona, *in* *History of Mining in Arizona*: J. M. Canty, H. M. Coggin, and M. N. Greeley (eds.), Mining Foundation of the Southwest, Volume 3, Chapter 5, p. 103-112.
- Vail, R. H., 1913, New Smelter of United Verde Copper Company: *Engineering and Mining Journal*, v. 96, n. 7, p. 287-292.
- Weed, W. H., 1916, *The Mines Handbook, an Enlargement of the Copper Handbook, A Manual of the Mining Industry of North America*: The Stevens Copper Handbook Co., New York, v. 12, 1699 p.

- Weed, W. H., 1918, International Edition the Mines Handbook, an Enlargement of the Copper Handbook, A Manual of the Mining Industry of the World: W. H. Weed, New York, v. 13, 1878 p.
- Weed, W. H., 1922, International Edition the Mines Handbook, succeeding the Copper Handbook: The Mines Handbook Company, Tuckahoe, New York, v. 15, 2248 p.
- White, D. C., 1986, Gold Distribution at the United Verde Extension, A Massive Base-Metal Sulfide Deposit, Jerome, Arizona, *in* Frontiers in Geology and Ore Deposits of Arizona and the Southwest: B. Beatty and P. A. K. Wilkinson (eds.), Arizona Geological Digest 16, p. 330-338.
- White, D. C., 1989, United Verde Exploration Proposal: Unpublished Report for A. F. Budge (Mining) Ltd., February 1989, 2 p.
- Woodward G. E., and Luff, P., 1945, Gold, Silver, Copper, Lead and Zinc in Arizona, *in* Minerals Yearbook 1943: C. E. Needham (ed.), U. S. Bureau of Mines, p. 237-264.
- Wright, P., 2009, [Phoenix Cement Celebrates 50 Years](https://www.verdenews.com/news/2009/oct/06/phoenix-cement-celebrates-50-years/): Verde Independent, October 6, 2009, (<https://www.verdenews.com/news/2009/oct/06/phoenix-cement-celebrates-50-years/>) .
- Young, H. V., 1930, Historical Sketch of the United Verde Copper Company, *in* The United Verde Copper Company: Reprinted from the Mining Congress Journal, April, 1930, p. 5-7.